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OF THE

New England Water Works Association.

1931—1932.

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THE ASSOCIATION was organized in Boston, Mass., on June 21, 1882, with the object of providing its members with means of social intercourse and for the exchange of knowledge pertaining to the construction and management of water works. From an original membership of only TWENTY-SEVEN, its growth has prospered until now it includes the names of 800 men. Its membership is divided into six classes, viz.:

A Member shall be an officer or employee of a public or private water works, an engineer, chemist or other person qualified to aid or interested in the advancement of knowledge relative to water works.

An Honorary Member shall be a person of acknowledged eminence in some branch of water supply or of engineering.

A Life Member shall be a member whose service to the Association entitles him to special recognition by the Association.

A Junior shall be not less than eighteen years nor more than twenty-five years of age, a student or connected with water supply work.

An Associate shall be either a person, firm or corporation engaged in manufacturing or furnishing materials or supplies for the construction or maintenance of water works.

A Corporate Member shall be either a Water Board, Commission, Company or Municipal Corporation.

The initiation fees and annual dues are as follows:

	Initiation Fees		*Annual Dues*
Members	$ 3.00	Members	$ 6.00
Juniors	1.00	Juniors	3.00
Associates	10.00	Associates	20.00
Corporate Members	10.00	Corporate Members	10.00

This Association has six regular meetings each year, all of which, except the annual convention in September, are held at Boston.

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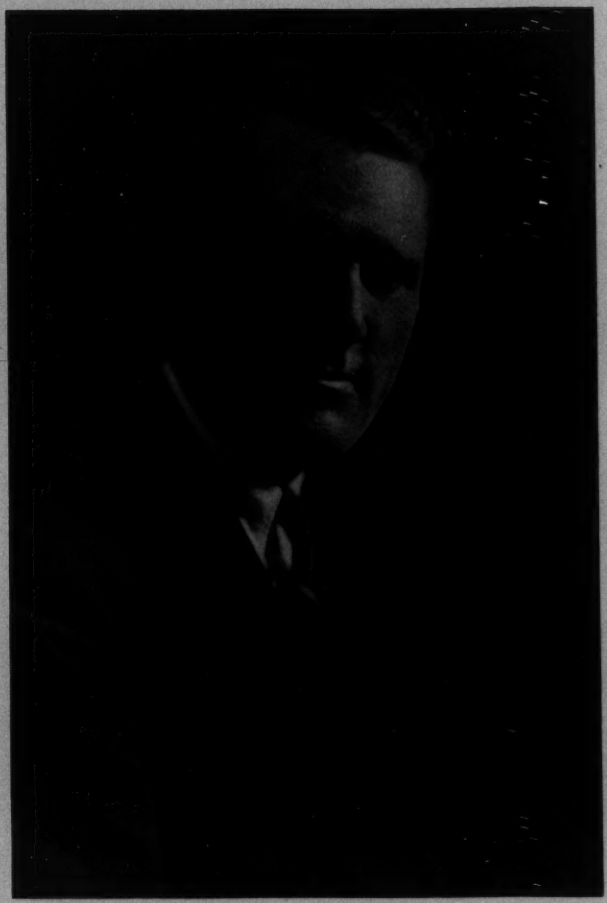


Photo by Bachrach

GEORGE C. BREHM.
President of the New England Water Works Association.
1931-1932.

New England Water Works Association

ORGANIZED 1882.

Vol. XLVI. March, 1932. No. 1.

This Association, as a body, is not responsible for the statements or opinions of any of its members.

HISTORY OF THE NEW ENGLAND WATER WORKS ASSOCIATION.

BY CHARLES W. SHERMAN.*

[*Read September 29, 1931.*]

On Feburary 17, 1882, the new superintendent of the New Bedford Water Works made a visit to Lowell to obtain some information about methods of operation there employed, and the superintendent of the Worcester Water Works also chanced to be there. Robert C. P. Coggeshall, Horace G. Holden, and Frank E. Hall, all strangers previous to that time, entered into conversation about the desirability of a society where water-works men could meet and exchange experiences. The American Water Works Association had recently organized, but these men felt that the chances of comparatively frequent contact and helpful association in a relatively small area were such as to justify the attempt to organize an association in New England. Later in the day two of them went to Lawrence and enlisted the assistance of Superintendent Henry W. Rogers; and these four men, with the addition of James W. Lyon of Salem (who was the first man to seriously suggest the formation of a water-works organization, beginning to discuss this matter in 1877) composed the committee which called the first meeting from which our Association has developed.

Mr. Coggeshall acted as Secretary of the committee and sent out a call for the first meeting, of which the following is a copy:†

OFFICE OF NEW BEDFORD WATER WORKS.
CITY HALL.
NEW BEDFORD, MASS.

R. C. P. Coggeshall, Supt.

March 16, 1882.

There is a movement being made to form an association of the water works managers of New England. This movement is endorsed by Mr. Lyon of Salem (who was the first to suggest the formation of such an organization), Mr. Holden of Lowell, Mr. Hall of Worcester, Mr. Rogers of Lawrence and others. This association is to meet once or twice a year in convention and exchange ideas. No doubt much profit as well as pleasure will be derived from these proposed gatherings. In order that the organization may be an assured success it is both necessary and important that there be a large attendance at a preliminary meeting which will be held on Wednesday, April 19th.

*Of Metcalf & Eddy, Consulting Engineers, Boston, Mass.

†Facsimile of the original letter appears on page 276, Vol. XVI, JOURNAL, New England Water Works Association.

The place of this meeting will be decided later, it will probably be Boston or vicinity. I am requested in the name of the informal committee mentioned above to extend an invitation to you to join the movement and to be present at the above named preliminary meeting. It is hoped that there will be a large representation of Registrars, Clerks, etc., as well as Superintendents. Should you find yourself interested we hope you will lend your influence by extending an invitation to be present at the preliminary meeting to all those whom you think would be interested.

Can you make it convenient to attend this preliminary meeting? If you wish I will advise you of the place of meeting as soon as it is decided.

Yours truly,

R. C. P. COGGESHALL.

In accordance with this call nineteen water-works officials met in Boston on April 19, 1882. The opinion that an association should be formed was overwhelming, and a committee was appointed to draft the constitution. On June 21, 1882 an adjourned meeting was held at Young's Hotel, Boston, with twenty-five water-works men present. The committee appointed at the previous meeting presented a draft of constitution and by-laws, which, after debate and a few changes, were adopted, and the first officers were elected. The President was James W. Lyon of Salem, the Secretary, Robert C. P. Coggeshall of New Bedford, and the Treasurer, Edwin Darling of Pawtucket, Rhode Island. The list of charter members includes 28 names, counting all those who had paid the prescribed fees before September 1882. These 28 men were:

Richard W. Bagnell, Plymouth, Mass.
James M. Battles, Lowell, Mass.
Robert C. P. Coggeshall, New Bedford, Mass.
J. Warren Cotton, Cambridge, Mass.
Edwin Darling, Pawtucket, R. I.
W. T. Dotten, Winchester, Mass.
Albert S. Glover, Newton, Mass.
Robert M. Gow, Medford, Mass.
Sherman E. Grannis, New Haven, Conn.
Frank E. Hall, Worcester, Mass.
Joseph C. Hancock, Springfield, Mass.
James H. Hathaway, Malden, Mass.
W. W. Hawkes, Malden, Mass.
W. F. Hill, Dedham, Mass.
Horace G. Holden, Lowell, Mass.
H. N. Hyde, Jr., Newton, Mass.
Addison Lane, Melrose, Mass.
Thomas C. Lovell, Fitchburg, Mass.
James W. Lyon, Salem, Mass.
A. H. Martine, Fall River, Mass.
Hiram Nevons, Cambridge, Mass.
Henry W. Rogers, Lawrence, Mass.
H. L. Schleiter, Meriden, Conn.
Phineas Sprague, Malden, Mass.
J. G. Tenney, Leominster, Mass.
Charles K. Walker, Manchester, N. H.
W. C. Wilcox, Waltham, Mass.

This meeting of June 21, 1882, is considered to mark the formal organization of the Association, and counts as its first convention. The present convention, also held in Boston, is therefore the fiftieth, although as a matter of fact the Association is only a little over 49 years old.

It is interesting to refer to the earlier attempts of Mr. Lyon to interest other water-works superintendents in the formation of a water-works association. His idea was that of a national organization, and he began as early as 1877 to discuss the matter with other superintendents whenever he happened to meet them. In March, 1879, he sent out a circular letter to every known water department in the United States and Canada, asking for expressions of opinion on the matter of forming such an organization. Although about 400 copies were sent out, but 70 replies were received, and Mr. Lyon thought that so little enthusiasm was shown that there was no object in proceeding. However, an examination of the replies received by Mr. Lyon, made by Mr. Coggeshall a number of years later, led the latter to feel that even though only 70 replies were received they showed sufficient interest to justify an attempt to organize a society, and that if sufficient energy had been devoted to it the American Water Works Association might have been organized in 1879 instead of 1881, and with Mr. Lyon as its founder.

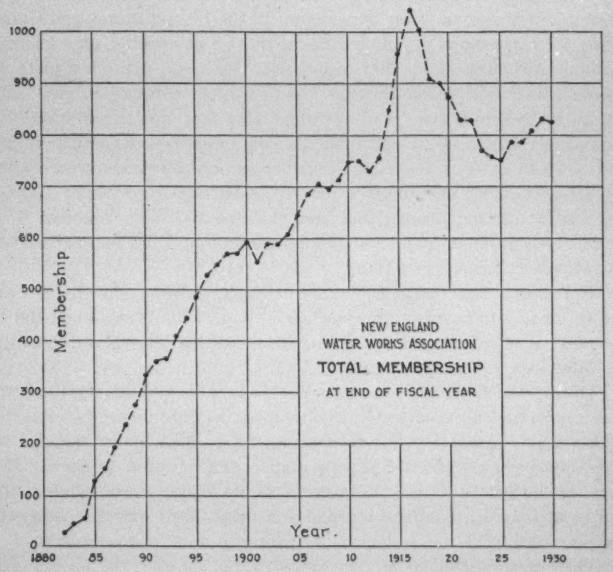
It is significant, perhaps, to note that in spite of Mr. Lyon's ideas and arguments in favor of an association, and of his being made the first President of our Association, he did not retain his interest sufficiently to pay dues longer than one year.

During the first three or four years, the Association remained small in numbers, and no great attempt was made to hold meetings more than twice a year. Annual volumes of proceedings, each about the size of a single quarterly number of the present JOURNAL, were printed. However, the Society and the enthusiasm of its members developed until, after a little, the quarterly journal was established and the scheme of holding monthly meetings during the winter months was adopted.

There is presented as an Appendix a table showing the names of the Presidents, Secretaries and Treasurers, the place of the annual convention and the total membership of the Association at the end of each fiscal year since its establishment. It will be noted that the growth in membership was rapid and fairly uniform from the beginning until the time of the World War, after which there followed a rapid fall in membership until 1925 when the total number was practically the same as in 1913. Since 1925 there has been a moderate and fairly uniform growth. The accompanying diagram shows in graphical form the changes in total membership.

While the meetings of the Association have always been marked by cordiality and good fellowship, a serious attempt for professional advancement was evident from the beginning of the Association. Technical papers and discussions have been the most important reasons for the

advancement of the Society, and a large percentage of the papers and committee reports presented have been of a high order of merit. Investigations and reports by committees of the Association have had an important influence in advancing water-works practice, in providing statistics of greatest value in water-works engineering, and in forwarding the cause of better and cleaner water supplies. Some papers by individual members have also been of such outstanding quality that they have been and still are quoted and referred to as of the greatest importance.



It seems desirable to record some of the particular accomplishments of committees, such as the standard specifications for cast-iron pipe; the specifications for water meters (adopted by a committee working jointly with one appointed by the American Water Works Association); statistics of consumption of water; statistics relating to the damages resulting from the diversion of water; statistics relating to the safe yield of sources of water supply; the promotion and ultimate adoption of a law in Massachusetts making water bills liens upon property in the case of municipally owned plants; a form for accounting for water utilities; dangers of cross-connections with polluted supplies; and the formulation of a logical method of devising suitable rates for metered water. A more recent accomplishment, and one which seems likely to be of much value

in the future, is the adoption of a scheme for the sanitary scoring of water supplies. In addition, extremely important papers have been presented before the Association upon the arrangement of hydrants and pipes for protection against fire (John R. Freeman), on quicksand (Charles R. Gow), on ground water as a source of supply (William S. Johnson), upon the use of copper sulphate to control microscopic organisms in reservoirs (various authors).

In the early days of the Association there were no headquarters, and the Secretary's office was at his home or at the office of the water department with which he was connected. In 1896 an arrangement was made with the Boston Society of Civil Engineers for rental of headquarters in Tremont Temple, and these headquarters have been maintained since that date. In more recent years the headquarters have been maintained by an affiliation of societies known first as the Affiliated Technical Societies of Boston, and more recently as the Engineering Societies of Boston. The New England Water Works Association has been one of the member societies of this organization since it was formed.

No historical sketch of the Association would be complete without special reference to some of the members who were most active in its organization and development. Preëminent among these was Robert C. P. Coggeshall. He was a charter member, the first Secretary of the Association (a position which he held from 1882 to 1884, and again from 1887 to 1895) and its President for the year 1885–1886. Mr. Coggeshall's energy and enthusiasm were the most potent influences in getting the Association under way and keeping it active during the first years, and he also had great influence in shaping its policies.

Mr. Coggeshall was born in New Bedford in 1849. He entered Rensselaer Polytechnic Institute, but left after a short time and worked in a surveying party on the New Bedford Water Works, then under construction. In 1872 he became draftsman and general assistant to the superintendent of the New Bedford Water Works; in 1877 city surveyor, and in 1881 superintendent of the New Bedford Water Works, a position which he held almost to the time of his death. He retired as superintendent early in 1922 and died later that year. He was made an Honorary Member of the Association in 1915.

Albert S. Glover, next to Mr. Coggeshall, should be mentioned as having a potent influence upon the development of the Association. He was born in South Boston in 1855. Later his parents removed to Newton, where he was graduated from the high school, after which he entered the Massachusetts Institute of Technology. He left the Institute in 1875 to take a position on the engineering force of the Boston Water Works, which was then building the Sudbury River aqueduct and reservoirs, and served most of the time until 1879 as secretary to Alphonse Fteley, the resident engineer in charge of these works. In 1879 he became Water Registrar of Newton, a position which he held until 1890. From that time

until his death in 1917 he was secretary of the Hersey Manufacturing Company and was engaged in the sale of water meters.

Mr. Glover was a charter member of the Association; he served as its Secretary from 1884 to 1887, and as Treasurer from 1887 to 1889. He was made an Honorary Member in 1915. Probably he was responsible in a larger degree than any other member, for the practice of obtaining full stenographic reports of all discussions, and for the establishment of the quarterly JOURNAL in place of the former annual issue of Proceedings.

After the opening of the headquarters in Tremont Temple, Mr. Glover had an office adjoining the rooms of the Association, and was always ready to give assistance in any matters which might promote its welfare. Few of the present members of the Association have any idea of the magnitude of his influence in shaping its policies and advancing its standing.

Dexter Brackett was born in Newton in 1851. In 1869 he entered the office of the city engineer of Boston. When only 22 years old he was assigned by city engineer Joseph P. Davis to the engineering for the improvement of the distribution system, considerable changes being found necessary after the Great Fire of 1872. Later he devoted much study to the detection and prevention of water waste. From 1888 to 1891 he was Superintendent of the Eastern Division (distribution system) of the Boston Water Works, but in the latter year he returned to the city engineer's office. In 1895 when the Metropolitan Water Works was organized, he became Engineer of the Distribution Department, and had charge of the piping system, pumping stations and distributing reservoirs of these works. In 1907 he became Chief Engineer, on the resignation of Frederic P. Stearns, and held this office until his death in 1915.

Mr. Brackett became a member of the Association in 1885, and was its President in the year 1889–1890. He presented a number of papers for the JOURNAL, and was a member of the committee which drafted the original standard specifications for cast-iron pipes and special castings. For a considerable period his influence in Association matters was so great that, had he desired, he could have dictated its policies and the selection of its officers. In recognition of the importance of his work the Dexter Brackett Memorial medal was established in 1917, and since that time a medal has been awarded each year to the member presenting the most meritorious paper.

These are but three of the many devoted members who gave unstintingly of their time and energy for the upbuilding and maintenance of our Association. There is no lack of the same disinterested service among the present officers and members, and there is every reason to believe that the Association will continue to be a powerful influence for the improvement of water-works practice.

APPENDIX.

NEW ENGLAND WATER WORKS ASSOCIATION.

Year.	President.	Secretary.	Treasurer.	Place of Convention.	Membership at End of Year.
1882	(Organization)			Boston, Mass.	28
1882–83	James W. Lyon*	Robert C. P. Coggeshall	Edwin Darling	Worcester, Mass.	43
1883–84	Frank E. Hall*	Robert C. P. Coggeshall	Edwin Darling	Lowell, Mass.	57
1884–85	George A. Ellis*	Albert S. Glover	Edwin Darling	Springfield, Mass.	127
1885–86	Robert C.P. Coggeshall*	Albert S. Glover	Edwin Darling	New Bedford, Mass.	153
1886–87	Henry W. Rogers*	Albert S. Glover	Edwin Darling	Manchester, N. H.	194
1887–88	Edwin Darling*	Robert C. P. Coggeshall	Albert S. Glover	Providence, R. I.	238
1888–89	Hiram Nevons*	Robert C. P. Coggeshall	Albert S. Glover	Fall River, Mass.	277
1889–90	Dexter Brackett*	Robert C. P. Coggeshall	Hiram Nevons	Portland, Me.	335
1890–91	Albert F. Noyes*	Robert C. P. Coggeshall	Hiram Nevons	Hartford, Conn.	360
1891–92	Horace G. Holden*	Robert C. P. Coggeshall	Hiram Nevons	Holyoke, Mass.	365
1892–93	George F. Chace*	Robert C. P. Coggeshall	Hiram Nevons	Worcester, Mass.	412
1893–94	George E. Batchelder*	Robert C. P. Coggeshall	Hiram Nevons	Boston, Mass.	443
1894–95	George A. Stacy*	Robert C. P. Coggeshall	George E. Batchelder	Burlington, Vt.	487
1895–96	Desmond FitzGerald*	John C. Whitney	George E. Batchelder	Lynn, Mass.	529
1896–97	John C. Haskell*	John C. Whitney	George E. Batchelder	Newport, R. I.	549
1897–98	Willard Kent*	John C. Whitney	George E. Batchelder	Portsmouth, N. H.	570
1898–99	Fayette F. Forbes	John C. Whitney	George E. Batchelder	Syracuse, N. Y.	572
1899–00	Byron I. Cook	Willard Kent	Lewis M. Bancroft	Rutland, Vt.	594
1901	Frank H. Crandall*	Willard Kent	Lewis M. Bancroft	Portland, Me.	555
1902	Frank E. Merrill	Willard Kent	Lewis M. Bancroft	Boston, Mass.	587
1903	Charles K. Walker*	Willard Kent	Lewis M. Bancroft	Montreal, P. Q.	586
1904	Edwin C. Brooks*	Willard Kent	Lewis M. Bancroft	Holyoke, Mass.	604
1905	George Bowers*	Willard Kent	Lewis M. Bancroft	New York, N. Y.	645
1906	William T. Sedgwick*	Willard Kent	Lewis M. Bancroft	White Mts., N. H.	684
1907	John Clifton Whitney	Willard Kent	Lewis M. Bancroft	Springfield, Mass.	702
1908	Alfred E. Martin*	Willard Kent	Lewis M. Bancroft	Atlantic City, N. J.	696
1909	Robert J. Thomas	Willard Kent	Lewis M. Bancroft	New York, N. Y.	715
1910	George A. King	Willard Kent	Lewis M. Bancroft	Rochester, N. Y.	747
1911	Allen Hazen*	Willard Kent	Lewis M. Bancroft	Gloucester, Mass.	750
1912	George W. Batchelder*	Willard Kent	Lewis M. Bancroft	Washington, D. C.	731
1913	J. Waldo Smith	Willard Kent	Lewis M. Bancroft	Philadelphia, Pa.	758
1914	Frank A. McInnes	Willard Kent	Lewis M. Bancroft	Boston, Mass.	847
1915	Leonard Metcalf*	Willard Kent	Lewis M. Bancroft	New York, N. Y.	961
1916	William F. Sullivan	Willard Kent	Lewis M. Bancroft	Portland, Me.	1 043
1917	Caleb Mills Saville	Willard Kent	Lewis M. Bancroft	Hartford, Conn.	1 002
1918	Carleton E. Davis	Willard Kent	Lewis M. Bancroft	Boston, Mass.	905
1919	Samuel E. Killam	Willard Kent	Lewis M. Bancroft	Albany, N. Y.	899
1920	Henry V. Macksey	Frank J. Gifford	Lewis M. Bancroft	Holyoke, Mass.	872
1921	Charles W. Sherman	Frank J. Gifford	Lewis M. Bancroft	Bridgeport, Conn.	828
1922	Frank A. Barbour	Frank J. Gifford	Frederic I. Winslow	New Bedford, Mass.	825
1923	Percy R. Sanders	Frank J. Gifford	Frederic I. Winslow	Burlington, Vt.	769
1923–24	David A. Heffernan	Frank J. Gifford	Frederic I. Winslow	Rochester, N. Y.	758
1924–25	Stephen H. Taylor	Frank J. Gifford	Albert L. Sawyer	St. Lawrence River	751
1925–26	Theodore L. Bristol	Frank J. Gifford	Albert L. Sawyer	Providence, R. I.	785
1926–27	Frank E. Winsor	Frank J. Gifford	Albert L. Sawyer	Boston, Mass.	783
1927–28	George A. Carpenter*	Frank J. Gifford	Albert L. Sawyer	Montreal, P. Q.	808
1928–29	Arthur D. Weston	Frank J. Gifford	Albert L. Sawyer	Portland, Me.	830
1929–30	Robert Spurr Weston	Frank J. Gifford	Albert L. Sawyer	Atlantic City, N. J.	822
1930–31	George H. Finneran	Frank J. Gifford	Albert L. Sawyer	Boston, Mass.	816

*Deceased.

THE BOSTON WATER SUPPLY.

BY FRANK A. McINNES.*

[*Read September 29, 1931.*]

In 1630, Governor Winthrop and his associates of the Massachusetts Bay Colony moved from Salem to Charlestown, with the intention of settling there; but after a brief stay the lack of good water caused them to change their plans, to cross the Charles River and to establish themselves in "Trimountaine" or "The Shawmut Peninsula" (now down-town Boston) where excellent springs were available; thus did the water problem determine the site of Boston.

The first recorded attempt to improve the water supply was made in 1652, when on petition of the inhabitants of Conduit Street (now Blackstone Street) "The Water Works Company" was incorporated and "The Ancient Conduit" was built; it consisted of a reservoir, about twelve feet square at the corner of Wing's Lane (now Elm Street) and Union Street, fed by pipes leading from springs and wells in the neighborhood; it manifestly did not help matters so far as the Colony as a whole was concerned.

In 1796, when the population was approximately 20 000, "The Aqueduct Corporation" was granted a charter and a gravity supply from Jamaica Pond was brought into the city through four main supply-pipes of jointed pine-logs, two of 4-in. and two of 3-in. bore; fifteen miles of these pipes were laid supplying about 1 500 houses in the South End and in the city proper. In 1840 a 10-in. cast-iron pipe was laid from Jamaica Pond to Bowdoin Square. This supply, owing to the low elevation of its source and its small capacity, could afford only a restricted domestic service to a limited number of consumers and provided practically no fire service. It simply ameliorated existing conditions to some extent.

The first step taken by the city of Boston towards an adequate water supply was in 1825 when a committee was appointed to enquire into the practicability, expense and expediency of supplying the city with pure water. The population was then about 59 000. For 195 years the necessity for action had become more and more pressing. Disastrous fires had caused great loss and suffering — the seventh "great fire" being recorded in 1792,— while unsanitary conditions, inevitable as the population increased, had become seriously dangerous. It is impossible for us living in this age of luxury to fully realize just what these conditions were in Boston 106 years ago.

A further delay of twenty years followed, during which the water supply question was ever to the fore. Many surveys and reports (including a notable one in 1834), were made, and many hearings were held. The com-

*Consulting Engineer, Boston, Mass.

paratively novel character of the enterprise, the differences of opinion which arose regarding the relative merits of sources, such as Long Pond, Charles River, Spot Pond, Mystic Lake and Jamaica Pond, and the large expense involved were too great a handicap to be quickly overcome.

THE COCHITUATE SYSTEM.

In 1848, the Legislature passed an act authorizing the introduction of water from Long Pond which was accepted by an almost unanimous vote of the citizens. The name of Long Pond was changed at this time to Lake Cochituate, its original Indian name. Ground was first broken for the new supply in August 1846, and the work was prosecuted with such vigor that water was introduced into the city through the new system, twenty-six months later, on October 25, 1848. This construction record conclusively proves that only the opportunity was required to give Boston an adequate water supply in record time.

The main features of the Cochituate supply are:

A storage reservoir, formed by raising the level of Lake Cochituate, situated about eighteen miles west of Boston within the limits of the towns of Framingham, Wayland and Natick, slightly supplemented by storage in Dug Pond and Dudley Pond, closely adjoining the lake. Its watershed is 19 sq. miles, its capacity 2 100 m.g., at high-water elevation 134.36 ft. above tide-marsh level. In order to exercise proper control over the water, 682 acres of marginal land entirely surrounding the lake and its outlet, were purchased or taken under authority of the act of 1846.

An aqueduct, 14.6 miles long, extending from Lake Cochituate to Brookline Reservoir, built of brick masonry with the exception of special construction near Newton Lower Falls, where an inverted siphon of cast-iron pipes is carried over the Charles River on a three-arch bridge of hammered granite, at an elevation about 52 ft. lower than the aqueduct grade on either side of the river. The masonry section is egg-shaped (with the large end down), 5 ft. wide and 6.33 ft. high on the inside, with 8-in. walls. Two rock tunnels, aggregating 3 560 ft. in length formed part of the construction. The capacity of the aqueduct is approximately 18 m.g.d.

A receiving reservoir in Brookline, into which the aqueduct discharges, with a capacity of approximately 90 m.g. High-water elevation 124.6 ft. above tide-marsh level.

A distributing reservoir on Beacon Hill with a capacity of 2 700 000 gal.

A distributing reservoir on Telegraph Hill, South Boston, with a capacity of 7 508 000 gal.

A distributing reservoir on Eagle Hill, East Boston, with a capacity of 5 600 000 gal.

Two compensating reservoirs in Hopkinton, with a capacity of 940 m.g., discharging into the Sudbury River and one in Marlborough, with a capacity of 1 400 m.g., discharging into the Assabet River. These reser-

voirs were acquired for the purpose of supplying to the proprietors of mill privileges on the Sudbury and Concord rivers and to the Middlesex Canal, a sufficient quantity of water in compensation for the amount drawn from Lake Cochituate for the supply of Boston.

A distributing system of cast-iron pipes, 4 to 36 inches in diameter. Two leading mains 36 and 30 inches in diameter were laid from Brookline Reservoir by way of Brookline Village to Roxbury Crossing, thence in Tremont Street to Dover Street where the 36-in. pipe was reduced to 30 inches and the two mains continued through Tremont Street to Boylston Street; one of them crosses the Common and passes over Beacon Hill to Chardon Street at Bowdoin Square; the other one passes easterly through Boylston Street to Washington Street where it reduces to 24 inches and continues in Washington, Moon, Merrimac and Chardon streets to a junction with the 30-in. main at Bowdoin Square. At Dover Street a 20-in. branch supplied South Boston. At the junction of Moon and Merrimac streets a 20-in. branch supplied East Boston. Twenty-, sixteen-, twelve-, six-, and four-inch mains distributed the water furnished by the leading mains. The distributing system, as briefly outlined, is a tribute to the ability and foresight of the designers. In October 1848, when water was first introduced, 57 miles of main pipe and 3 600 services had been laid. On January 1, 1850, 81.5 miles of mains, 916 hydrants and 13 341 services were in use; at this time the total cost of Boston's first adequate water supply was $4 000-000 in round numbers; the population of the city was then approximately 136 000.

In 1852, the Cochituate Water Board addressed a communication to the Mayor of Boston recommending that meters be installed in any places thought advisable and that the wanton and illegal use of water be made a penal offense punishable by fine; this action was occasioned by the fact that the average per capita consumption had risen to 60 g.p.d., a quantity of water twice as great as that originally estimated for the needs of the city.

The mains and service pipes were laid four feet deep as measured from the surface of the ground to the center of the pipe. In 1865, owing to the disastrous effects of frost, this depth was increased to four and one half feet and in 1872, for the same reason as before, to five feet, which practice still prevails.

The designers of the Cochituate system faced a serious handicap from the lack of precedent, as is exemplified in the two preceding paragraphs; yet, despite all obstacles the entire construction has served its purpose in a remarkably efficient manner.

The consulting engineer and the chief engineers of the two divisions of the work were each paid $3 000 per annum for their services, which must have been arduous.

In 1851, the city purchased the property of the Jamaica Pond Aqueduct Company for $45 217.50; in 1856 this property was resold for $32-

000.00 to private parties in Roxbury, to which territory the mains of the Aqueduct Company extended.

In 1865, the construction of Chestnut Hill Reservoir, in the line of the Cochituate Aqueduct, was authorized. The work was begun the same year and completed in 1870, with the result that an invaluable supply of water was made available about 5½ miles from Boston City Hall in the event of interruption in the flow of the Aqueduct. The reservoir capacity is 731 m.g. at grade 134 above Boston City Base.*

The annexation of Roxbury in 1868 made high service necessary, as part of the acquired territory was too high to be supplied by gravity from Lake Cochituate. In 1870 the higher service was put in operation with a pumping station at Elmwood Park, Roxbury equipped with two non-condensing, direct-acting pumping engines and a standpipe on the "Old Fort Lot" in Roxbury, the site of an earth work at the time of the Revolutionary War. High service was also extended to Beacon Hill at this time. The annexation of Dorchester in 1870 increased the demand for high service, and in 1872 it was extended through a portion of the higher part of Dorchester and to Telegraph Hill, South Boston.

The population of Boston in 1867 was approximately 200 000, the rate of increase for the decade 1855 to 1865 having been a little in excess of 19 per cent. At this time, when the annexation of Roxbury was under consideration, the Cochituate Water Board sounded a note of warning with the statement that a new source of water supply would be needed within five years if 30 000 consumers were added from Roxbury. Unfortunately dry years followed and in 1871–1872 a water famine was averted by pumping 2 250 m.g. of water from Lake Cochituate into the aqueduct, for the supply of Boston. In 1872, a temporary connection from the Sudbury River was made, affording a much needed reinforcement. In 1873, the supply was further increased from 2 to 2½ m.g.d. by a connection with the Mystic Works, then supplying Charlestown, Chelsea, Somerville and Everett. In 1874, a second water famine was forestalled by putting into service, for a period of ninety days, the pumping equipment previously used in 1871–1872. The foregoing statements are evidence that some of the trials and tribulations of today were not unknown to water-works men sixty years ago.

In 1872, the first major step was taken to supplement the supply from Lake Cochituate, when an act of the Legislature was passed authorizing an additional supply from the Sudbury River.

The Sudbury System.

Actual construction of the permanent works began in 1875, and the new additional supply was put in service in 1878. The watershed of 75 sq. miles includes the town of Southborough and large parts of the surrounding towns. Storage is provided in five reservoirs and in Whitehall Pond:

*All elevations hereafter given in this paper refer to Boston City Base.

Reservoir No. 1 and No. 2 being on the Sudbury River, Reservoir No. 4 and No. 6 and Whitehall Pond on streams flowing into the river from the south and Reservoir No. 3 and No. 5 on Stony Brook entering the river from the northwest. Reservoir No. 1, 2 and 3 were put in service in 1878, Reservoir No. 4 in 1885, Reservoir No. 6 and Whitehall Pond in 1894. Reservoir No. 5 was taken by the Metropolitan Water Board in 1896 while under construction by the city of Boston.

The Sudbury Aqueduct, as originally constructed, extended from Reservoir No. 1 to Farm Pond into which it discharged; thence to Chestnut Hill Reservoir, a total distance of about 16.7 miles. In general, it is constructed of masonry with a foundation of concrete and side walls of rubble stone laid in cement. The bottom and sides were lined with brick, and a brick arch completed the structure. Its size, on the inside, ranges from 6.88 ft. high and 7 ft. wide to 7.67 ft. high and 9 ft. wide, depending upon its grade. In its length are five tunnels. At the crossing of Charles River in West Newton the aqueduct is carried on a notable granite masonry bridge of seven arches; at the crossing of Waban Brook in Wellesley it is again carried on a masonry bridge of nine arches; at Rosemary Brook in Wellesley it is carried through a siphon of 48-in. pipes. In 1886 the masonry aqueduct was extended across Farm Pond in Framingham making it possible to deliver the Sudbury supply to Chestnut Hill Reservoir without mingling with the waters of the pond. The capacity of the aqueduct when running full is 103 m.g.d.

The capacity of the combined Cochituate and Sudbury supplies in a series of dry years is approximately 55 m.g.d. The water from these sources does not measure up to the high standards of today and is used only to a limited extent in the supply of the Metropolitan District.

The first biological laboratory in connection with a water works department in this country was established in 1868 at Chestnut Hill Reservoir, and systematic analyses and examinations of the water were thereafter made. Other precautions taken to safeguard the water supply were the construction of sewerage systems in Marlborough, Westborough and Framingham with outlets discharging outside the Sudbury watershed. In addition to the diversion of sewage, the water of Pegan Brook flowing from the village of Natick into Lake Cochituate is purified by being pumped upon filter beds, constructed for the purpose. The water of two brooks flowing from the city of Marlborough and the town of Natick is also purified by passing through filter beds.

Mystic Lake Supply.

This supply was developed by the city of Charlestown in 1864, acquired by Boston in 1876, became the property of the state of Massachusetts in 1898 under the provisions of the Metropolitan Water Act of 1895, and was at that time abandoned as a source of water supply.

Its safe yield in a period of dry years was about 7 m.g.d., the water being of a decidedly inferior quality. This source supplied Charlestown until 1898 and East Boston at intervals between 1870 and 1876.

The annexation of Charlestown, Brighton and Roxbury in 1874, together with the rapid increase of population throughout the city made further extension of the high service, on a much larger scale than heretofore, imperatively necessary. In 1877, Parker Hill Reservoir in Roxbury, capacity 7 200 000 gal., high-water elevation 241 ft. was completed and put in service. In the same year a compound duplex pumping engine with a capacity of 3 m.g.d. was installed in Elmwood Street Pumping Station. In 1887, Fisher Hill Reservoir in Brookline, capacity 15 500 000 gal. high-water elevation 251 ft., was completed. In the following year a pumping station at Chestnut Hill Reservoir was put in service, equipped with two horizontal compound pumps, each with a capacity of 8 m.g.d. In 1894, a notable pump of 20-m.g.d. capacity, of special design and of record duty was installed in Chestnut Hill Pumping Station. Elmwood Street Pumping Station was abandoned at this time, as was a small temporary pumping station in Brighton. Parker Hill Reservoir was also abandoned a little later. From Chestnut Hill Pumping Station large force mains extend to Fisher Hill Reservoir, whence high service mains 48 to 20 inches in diameter extend to the city proper, Roxbury, West Roxbury, Dorchester, etc.

In 1893, the pipe system of the Jamaica Pond Aqueduct Corporation, consisting of about nine miles of cast-iron mains in Roxbury, was purchased by the city of Boston for $75 000 and connected with its distribution system.

The Metropolitan Supply.

From this point forward, the stories of the Boston Water Works and the Metropolitan Water Works have so much in common that the latter forces itself into the picture, despite the title of this paper.

Approximately fifteen years after the supply from the Sudbury River was put into service, it was apparent that the city of Boston must again look for more water. At the same time a number of other cities and towns surrounding Boston were facing serious difficulties resulting from an inadequate source of supply or from an inferior quality of water. In 1893, Chapter 459 of the Acts of 1893 authorized the State Board of Health to report upon the question of a water supply for the city of Boston and its suburbs within a radius of ten miles from the State House and for such other cities and towns as in its opinion should be included in connection therewith. This report was made early in January 1895, and the Metropolitan Water Act, Chapter 488 of the Acts of 1895, based on the report of the State Board of Health, was approved June 5, 1895. It provided that the Governor, by and with the consent of his Council, should appoint three men to constitute the Metropolitan Water Board; the duty of this Board

being to construct, maintain and operate a water supply, at a pressure sufficient for all purposes, for the cities and towns in a Metropolitan District, closely defined as the territory within ten miles of the State House. Other provisions of the Act were that the Board was authorized to take the supply from the South Branch of the Nashua River at and above the dam at the Lancaster Mills in the town of Clinton and that it should take, if necessary, all or part of any water system in the cities and towns of the Metropolitan District.

Work on the new supply was begun in 1895 and was practically completed in 1906.

In general, the construction consisted of a notably large dam at Clinton forming the Wachusett Reservoir; an aqueduct and open channel from this dam to Sudbury Reservoir which was being constructed by the city of Boston in its Sudbury River system under the designation of Basin 5 when it was taken by the state in 1896 and afterwards completed; thence part of the supply for the Metropolitan District flows through the Sudbury and Cochituate aqueducts to Chestnut Hill Reservoir, the remaining part being carried by the Sudbury Aqueduct extending from Sudbury Reservoir to a terminal chamber in the town of Weston near the Charles River from which point it is distributed by pipe lines throughout the Metropolitan District.

In 1901, the Metropolitan Water Board was abolished, its duties being transferred to the Metropolitan Water and Sewerage Board.

The following is a description in greater detail of the principal features of the Wachusett Supply.

The Wachusett Storage Reservoir, located in the towns of Clinton, Boylston and West Boylston, is formed by a dam on the southwest branch of the Nashua River in the vicinity of the settled portion of the town of Clinton and by two earth dykes above the main dam. The reservoir is the largest body of fresh water in Massachusetts; it is 8.4 miles long with a maximum width of 2 miles, an area of water surface of 6.56 sq. miles, a maximum depth of 129 ft., an average depth of 46 ft. and capacity, at high-water elevation 396.5, of 67 billion gallons. The area overflowed by the impounded water contained six large mills, eight schoolhouses, four churches and 360 buildings, all of which were demolished or removed; in addition it was necessary to relocate, outside of the limits of the reservoir 19½ miles of highways and 6½ miles of railroad. The soil was stripped from 3 943 acres of the botton of the reservoir, and gravel to the depth of one foot was spread where deep deposits of muck existed. The watershed of the reservoir contains 69 persons to the square mile.

The Wachusett Dam, one of the notable structures of its kind in the world, crosses a narrow gorge of the southwest branch of the Nashua River at a point about one-half mile above the dam of the Lancaster Mills at Clinton. It is built of granite rubble masonry, with its top twenty feet above high water in the reservoir; it is 944 ft. long, 207 ft. high from its top

to the point of deepest excavation and 85 ft. thick at a point 95 ft. below the level of the reservoir when full. Adjoining the dam at its northerly end is a wasteway 452 ft. long and a waste channel large enough to safely carry an 8-in. depth of water over the entire watershed in 24 hours.

The Wachusett Aqueduct is built in rock tunnel for two miles from its upper end, followed by a masonry structure, including a bridge over the Assabet River, for seven miles, with three miles of open channel at the lower end. The tunnel section, where lined, is 12 ft. 2 in. wide and 10 ft. 10 in. high, of horseshoe shape; the masonry section, 11 ft. 6 in. wide and 10 ft. 6 in. high, also of horseshoe shape, is constructed with bottom and side walls of Rosendale cement concrete, lined with 4 in. of brick and with a semi-circular arch covering of Portland cement concrete. The open channel is 20 ft. wide on the bottom with side slopes of three horizontal to one vertical. Its capacity is 360 m.g.d.

The Sudbury Storage Reservoir is located in the towns of Southborough and Marlborough on the Stony Brook Branch of the Sudbury Reservoir; its dam, 2 165 ft. long, is formed by an earth embankment with an included concrete core wall founded on solid rock, and with a granite masonry waste way approximately in the middle of its length. Its capacity, at high-water elevation 260 ft., is 7 253 500 000 gal.

The Weston Aqueduct, capacity 300 m.g.d., extends from the Sudbury Reservoir to a terminal chamber in the town of Weston, a distance of 13.4 miles; for the first 500 ft. the water is carried through 60-in. cast-iron pipes to a head house; thence a masonry aqueduct, discharging into an open channel, extends about 10¼ miles, with the exception of the crossings of the Sudbury River and of Happy Hollow, where steel pipe 7½ ft. in diameter provides for the flow; the open channel, 12 ft. deep and 10 ft. wide at the bottom, discharges into Weston Reservoir, from the screen chamber of which the masonry aqueduct extends a distance of 5 658 ft. to the terminal chamber near the Charles River.

The aqueduct is horseshoe-shaped, varying in size, according to its grade, from 10 ft. wide by 9 ft. 3 in. high to 13 ft. wide by 12 ft. 2 in. high. Five tunnels aggregating 23 miles in length were constructed in the line of the aqueduct, all of which were lined with concrete; otherwise the aqueduct was built with invert and side walls of Rosendale cement concrete, lined with 4 inches of brick; the arch was of Portland cement concrete.

The Weston Distribution Reservoir, located in the line of the Weston Aqueduct; with a capacity, at high-water elevation 200 ft., of 200 m.g.

The total area of the Cochituate, Sudbury and Wachusett watersheds is approximately 200 sq. miles; within it are nine storage reservoirs with a total capacity at high-water mark of 82 544 600 000 gal., together with twelve distribution reservoirs with a capacity of 2 400 680 000 gal.

The principal takings made by the Metropolitan Water Board were as follows:

In 1896, Basin 5 in the Sudbury system then under construction by

the city of Boston was taken and afterwards completed by the Metropolitan Board.

In 1898, practically the entire works of supply of the Sudbury and Cochituate systems, Chestnut Hill Reservoir and Pumping Station and the supply works of the Mystic system were taken.

In 1913, Fisher Hill Reservoir, the large supply mains in Brookline from Chestnut Hill and Fisher Hill Reservoirs to the Boston line and similar mains in Somerville from the Mystic Reservoir on Tufts Hill to the Charlestown line, were taken.

The total amount paid by the Commonwealth to the city of Boston in compensation for the above takings and for interest due in connection therewith was $13 927 000 in round numbers.

In 1919, the Metropolitan Water and Sewerage Board was abolished, its duties being transferred to the Metropolitan District Commission, with the Metropolitan Water Works functioning as the Water Division of the new Commission.

About twenty-two years after water from Wachusett Reservoir was first used to supply the Metropolitan District it was apparent that an addition to the existing sources of supply was necessary for the third time. A report recommending extension to the Ware and Swift Rivers was made by the State Department of Health to the Legislature in 1922, followed by an independent investigation and report by a commission in 1924–1925. On May 28, 1926, Chapter 375 of the Acts of 1926 became law creating the Metropolitan District Water Supply Commission with authority to increase the existing Metropolitan supply by diverting the water from about 98 sq. miles of the drainage area of the Ware River, in excess of 85 m.g.d., during the months of January to May inclusive, and also during the balance of the year with the approval of the State Department of Health.

This Act also directed the Commission to submit to the General Court in January 1927 "a draft of such legislation as it may deem necessary or advisable for the development of an adequate future supply from the Swift River."

The Swift River Act was enacted on April 26, 1927.

The principal features of the new supply authorized by the Legislature consist of a tunnel from Wachusett Reservoir to the Swift River into which the Ware River supply enters through a shaft of the tunnel, together with the works necessary for intake, storage, etc. at the two rivers.

Construction began in March, 1927 on the tunnel from Wachusett Reservoir to the Ware River, and water from the Ware flowed into the reservoir on March 14, 1931, since which time it has formed part of the Metropolitan supply.

The Ware Tunnel 14 miles long, was driven in rock by means of eight shafts varying from 215 to 656 ft. in depth. It is of horseshoe shape, 12 ft. 9 in. high by 11 ft. wide and is lined with concrete throughout its length.

The Intake Works consist of a diversion dam, surface control works

and an entrance shaft designed to dissipate the energy due to a drop of 260 ft. into the tunnel by a spiral flow in the shaft, at the same time excluding the air from the water so far as possible and measuring the flow of water.

Work on the extension of the tunnel to the Swift River is now in progress; its completion will provide a means for carrying the Swift River supply to Wachusett Reservoir and will also make it possible to store water from the Ware River in the Swift River Reservoir. The reservoir to be built on this system will be about six times larger than Wachusett Reservoir and will store at least 300 billion gallons of water.

The supply from the Ware River will furnish about 27 m.g.d., an increase estimated to make the Metropolitan supply sufficient until water from the Swift River, without storage, will be available. When the Swift River system is completed the combined supplies from the Ware and Swift rivers will add about 194 m.g.d. to the Metropolitan Supply.

The Metropolitan Water District.

The Metropolitan Water District comprises an area of 174 sq. miles with a population of approximately 1½ million people. The following municipalities within it are regularly supplied from the Metropolitan Water Works: Arlington, Belmont, Boston, Chelsea, Everett, Lexington, Malden, Medford, Melrose, Milton, Nahant, Quincy, Revere, Somerville, Stoneham, Swampscott, Watertown and Winthrop. A partial supply is furnished to Brookline and Newton.

The total length of main pipe laid and maintained by the Metropolitan Board, from 16 to 60 inches in diameter, was 150.4 miles on December 31, 1930.

At Chestnut Hill Reservoir, two pumping stations are operated equipped with 16 pumping engines, 14 vertical fire-tube boilers and 5 horizontal return-tube boilers. The aggregate horse power of the engines is 6 100 with a pumping capacity of 282 m.g.d.

During the year ending November 30, 1930, 49 792 038 000 gal. of water were furnished to the 18 municipalities regularly supplied. This is equivalent to an average daily consumption of 136 416 500 gal. and a per capita consumption of 98.2 g.p.d. The average daily consumption of Boston during the same period was 92 286 000 gal. or practically 68 per cent. of the whole, its per capita rate being 118 g.p.d. on the basis of a population of 781 200.

The water supply to each municipality is determined by meter measurement through 69 Venturi meters. An assessment covering maintenance, interest and sinking-fund charges is made upon the different municipalities on the basis of two thirds of their respective consumption of water and one third of their respective valuations. Under these conditions the saving of water should be considered a matter of first importance by the

cities and towns in the district, inasmuch as the consumption of each municipality plays so large a part in fixing the amount of the assessment.

The quality of the water supplied to the Metropolitan District has been protected by the taking of large areas of land around the reservoirs and along streams flowing into them, by the construction of many miles of ditches to drain swamps in the watersheds and by the construction and operation of filters at a number of places where danger of pollution from surface drainage existed.

A constant inspection of the watersheds in the system is maintained to prevent pollution of the water by enforcing the sanitary rules and regulations.

Chemical examinations of the water in the different reservoirs are made monthly by the State Department of Health, and observations of the color and odor of the water together with the number and character of organisms present in the water are made weekly in the laboratory of the Metropolitan Commission.

The water supplied to the District is disinfected by chlorine when such treatment is considered necessary.

Boston Water Department.

The taking, by the state of Massachusetts in 1898, of practically the entire Boston water-supply system outside of the city limits, radically changed the former significance of the term "Boston Water Works." Under the new conditions the responsibility of providing water in sufficient quantity and at necessary pressure became the duty of the Metropolitan Water Board, the city retaining ownership in little more than its distribution system, the operation and maintenance of which, however, constitutes a most important responsibility.

Authority over the water system was vested in a Board of Water Commissioners, with the City Engineer acting in an advisory capacity, from 1849 to 1895, when a single Commissioner replaced the Board; this organization continued until the Public Works Department was created and the office of City Engineer was abolished in 1911. Since that date the organization of the Water Department has been as follows: A Division Engineer of Water Service, reporting directly to the Commissioner of Public Works and having charge of the three divisions of the service, viz: The Engineering Branch, the Income and Meter Branch and the Distribution Branch.

The Engineering Branch functions as its name indicates; its four Assistant Engineers directing the force of draughtsmen, rodmen, inspectors, etc., report to the Division Engineer. One of the duties of this branch is the inspection of materials used in construction at points of manufacture.

The Income and Meter Branch is directed by an Engineer In Charge, reporting to the Division Engineer. Among his duties are the determination

of the size and number of new service and other pipes to premises; the reading of meters four times a year, the making out of water bills, the installation of new meters and the restriction of water in general. Another oftentimes trying duty is the adjustment of water bills.

A meter shop is maintained with modern facilities for testing and repairing new and old water meters.

Meters are now sealed, when installed, to prevent tampering on the part of consumers with an easy conscience.

A Legislative Act of 1907 provided that meters should be set on all new services and that five per cent. of existing unmetered service should be provided with meters each successive year. The time for completion of this work was extended two years on account of the World War. The city lived up to its obligation, and meters are now in operation in every active service, their number being 100 000 in round numbers. The result of this universal metering has been, as might be expected, a notable decrease in consumption.

The water rates for each 1 000 cu. ft., computed quarterly, are:

First 20 000 cu. ft.	$1.84
Second 20 000 cu. ft.	$1.71
Third 20 000 cu. ft. and up to 1 000 000 cu. ft.	$1.58
Over 1 000 000 cu. ft.	$1.05

Minimum rate $10.00 per annum.

The receipts from the sale of water were $4 971 000 in 1930 and $4 875 000 in 1931.

The Distribution Branch is in charge of a General Superintendent, reporting to the Division Engineer. It is directly concerned with extensions, repairs and maintenance matters in general. The city is divided into six suburban districts each with a foreman, local headquarters and working force, and a central district with four foremen and gangs who take care of the troublesome repairs and emergencies that occur in the city proper.

The distribution system consists of approximately 951 miles of mains, 4 to 48 inches in diameter. All mains are of cast iron with the exception of a 20-in. wrought-iron cement-lined pipe 6 100 ft. long laid in Medford Street, Charlestown in 1870 and a comparatively small amount of steel pipe including three quarters of a mile of 48-in., electrically welded pipe, just installed, and scattered short sections throughout the city, principally over bridges.

Mains supplying South Boston are carried under Fort Point Channel in tunnels at Congress and Dover streets. The same construction was employed under the south channel of the Mystic River, between Charlestown and Chelsea, in the case of a 30-in. main supplying East Boston.

In the system are approximately 10 910 hydrants, 14 867 gate valves, 775 blow-off valves and 99 891 service pipes. All gate valves and hydrants open to the right and are of solid-wedge type.

The gridiron is strongly reinforced by secondary 16- and 12-in. mains and is well cross-connected throughout, dead ends being comparatively few in number. An ample supply of water is available for fire purposes at practically all points in the system. The Harbor Service, including Deer Island, Thompson's Island, Spectacle Island, Gallup's Island, Lovell's Island and Georges Island, is supplied by flexible cast-iron mains laid in trenches under the harbor bottom from the mainland to the several distribution systems.

A machine shop is maintained where the greater part of the brass fittings and approximately one half of the hydrants and gate valves 4- to 24-in. in size are manufactured. The city owns its own patterns for service-box fittings, gate boxes, hydrants and gate valves of all sizes. When this material is purchased outside, the necessary castings are furnished to the contracting party, to be manufactured, other than in the case of 30- and 36-in. gate valves, where the patterns only are furnished.

Three emergency crews with three trucks are maintained on a twenty-four hour basis, two of the trucks being fitted with a gate-closing mechanism operated by the engine of the truck. An emergency gang responds to all third-alarm fires.

Tapping machines are used exclusively in making connection with existing mains and in establishing hydrants, services, etc. Power-driven pipe cutters are used in cutting pipe 6 to 48 inches in diameter.

The compression type of post hydrant is used. About ten per cent. of the hydrants in the system are of the flush type, requiring the removal of cover and attachment of chuck before operation; they are usually located in the street over the main pipe and occasionally in the sidewalk.

Lead service-pipes were almost exclusively used up to 1928, when the use of copper for 2-in. services began; its use is now being extended to all service pipes up to 2 inches in diameter.

Newly laid mains are disinfected by hypochlorite of lime, if any possible danger is thought to exist.

Curb boxes are established on all services to permit control of the sidewalk shut-off; in addition a box is set over the corporation cock in the street and is usually carried up to within about fifteen inches of the street surface, although the practice of carrying these boxes to the street surface is increasing. The object of this construction is, of course, to allow a service pipe to be shut off at the main pipe by excavating a small hole in the street.

The department aims to be thoroughly modern. Part of its equipment is: Seven portable power-driven air-compressors; six trucks equipped with derricks operated by the engine of the truck; a 7-ton power-operated derrick in the main supply-yard; portable outfits for thawing frozen pipes; power pipe-cutters; automobiles, etc.

Underground congestion in the down-town streets makes the work of maintenance difficult and expensive. In many streets are found three or more water pipes, two or more gas pipes, one or more sewers and the ever

present conduits, ducts, pipes, etc. which provide steam heating, electric service, telephone service, etc. Add to this list the inevitable manholes, house drains, water-service pipes, hydrant pipes, etc. and the result is a very serious congestion, providing genuine "Chinese puzzles" when the time comes to repair or relay the water pipes.

The system is operated in four different services at pressures made necessary by the varying elevations of the ground which range from grade 16 to grade 336.

The Low Service comprises the city proper with the exception of Beacon Hill and the neighboring area bounded westerly by Tremont and Somerset streets, southerly by Boylston Street, easterly by Washington Street and northerly by Court Street and Tremont Row; the greater part of South Boston; one half of Brighton; one half of Roxbury; a small part of Dorchester and West Roxbury; the greater part of Charlestown; the greater part of East Boston; and Deer Island. This service is supplied with Metropolitan water largely by gravity, pumping being resorted to at certain periods only.

The Southern High Service, supplied by pumping from Chestnut Hill Reservoir, comprises Beacon Hill and an adjacent area bounded westerly by Tremont and Somerset streets, southerly by Boylston Street, easterly by Washington Street and northerly by Court Street and Tremont Row; Bunker Hill in Charlestown, Telegraph Hill and neighboring high land in South Boston, one-half of Brighton, one half of Roxbury, the greater portions of Dorchester, West Roxbury and Hyde Park together with six Islands in Boston Harbor. High-service mains are also laid extensively in the low service area to afford fire protection through sprinkler and inside hose systems; they furnish domestic service as well to buildings too high to be supplied by low service.

The Southern Double High Service includes the higher portions of West Roxbury and Hyde Park. The supply for this service is furnished by a pumping station in Hyde Park taking suction from the Southern High Service operated by the Metropolitan District Commission. A standpipe on Mount Bellevue, West Roxbury, maintained by the Metropolitan Commission, safeguards this system.

The Northern High Service comprises the Breed's Hill area in East Boston.

Flexibility of operation in time of trouble is afforded by the large number of gates which are normally kept closed between the different services and by six closed Metropolitan gates in the system.

Emergency connections, ranging from 6 to 12 inches in diameter, with closed gates, have been made with adjoining distribution systems in Chelsea, Winthrop, Somerville, Newton, Brookline, Dedham, Milton, Quincy and Atlantic.

High Pressure Fire Service.

This service was installed and its distribution system is maintained by the Water Department; it is the "strong arm" of the Boston Fire Department and has been called upon many times in the past ten years to prove its value. It has never failed to function successfully, nor to prevent a fire spreading dangerously in the square mile of area in the congested high-value district which it protects.

Four pumping units in two stations, 18½ miles of 20-, 16- and 12-in. cast-iron mains and 502 hydrants constitute the main features of the system. Pumping Station No. 1 is located in the basement of the Power Station of the Boston Elevated Railway at the corner of Commercial and Battery streets. The equipment includes two Worthington three-stage double-suction centrifugal pumps, each direct-connected to a Westinghouse 750-h.p. steam turbine of the horizontal impulse type. At 200 lb. per sq.in. pressure, each pump will deliver 5 000 g.p.m. The pumping equipment in this station is now being transferred to a new location in the Power House of the Edison Electric Illuminating Co. on Beach Street.

Pumping Station No. 2 is located in a fireproof building, constructed for the purpose, within the large boiler room of the Edison Electric Company's station on Atlantic Avenue at the foot of Pearl Street. The equipment includes two Worthington two-stage single-suction centrifugal pumps, each direct-connected through semi-flexible couplings to a Westinghouse 750-h.p., 235-volt, D.C. shunt-wound interpole motor with a speed range from 860 to 1 050 r.p.m. At 200 lb. per sq. in. pressure, each pump will deliver 5 000 g.p.m.

Two 16-in. suction mains connect with the low-service and high-service distribution systems of the city. As an added precaution a 16-in. suction main connects with a large intake conduit supplying salt water from Boston Harbor to the Edison Station for condensing purposes.

The water piping is of cast iron, each pipe in force mains being separately tested at a pressure of 600 lb. per sq. in. before being assembled. The principal control valves are electrically operated, by Deane control. Operating pressures are controlled by means of Ross regulating valves between the suction and discharge of each pump. The entire equipment is operated from the switchboard, making it easily possible for one man to make available a fire pressure of 150 lb. per sq. in. at the hydrants within less than a minute after a fire alarm is received at the station. In the event of failure of the fresh-water supply, the pumps can be primed and ready for service with salt water in less than three minutes' time.

The straight pipe and special castings of the distribution system are of cast iron, except in the case of branches where the opening from the run is 12 in. or over, when semi-steel is used. All pipes were subjected at the foundry to a hammer test at 500 lb. per sq. in. Two lead grooves are cast in the bell end and two in the spigot end of each pipe.

The joint material used, where unbalanced pressures exist or might develop, is an alloy of 95 per cent. lead and 5 per cent. tin. Extensive preliminary tests showed that this material increased the strength of the joints sufficiently to safely permit tie rods or other supports to be dispensed with; a conclusion that has been amply verified in actual service. The pipe lines were tested, when laid, for a period of one hour at a pressure of 400 lb. per sq. in., and little or no difficulty was experienced in keeping the joint leakage down to $\frac{1}{2}$ gal. per linear foot of pipe joint per 24 hours.

The post hydrant is of rugged design, with $8\frac{1}{2}$-in. barrel, $6\frac{1}{8}$-in. main-valve, opening against the pressure, and four $2\frac{1}{2}$-in. independently controlled outlets.

The gate valves are of the solid wedge type, bronze mounted with bodies and bonnets of semi-steel. Gate stems are of monel metal. Each gate was tested for strength at 500 lb. per sq. in., for leakage at 450 and for operation at 300 lb. per sq. in.

No pipes supplying sprinklers or other inside fire protection are connected with the mains of the system, the only outlets being the hydrant nozzles.

Conclusion.

The Metropolitan Water System is now furnishing to Boston and the other cities and towns in its district an ample supply of excellent water, and it is confidently and reasonably estimated that it will safely continue to do so for forty years to come.

It is interesting to note that each of the four successive developments of the system have been made in the same general direction towards the setting sun, despite the fact that three of its five watersheds drain southeasterly into the Merrimac River, the remaining two northwesterly to the Connecticut River. Another feature, appealing to the imagination at least, is the physical possibility of taking a fifth step westerly beyond the Connecticut River to the valleys of the Deerfield and Westfield rivers where a supply of water of the best quality is available from drainage areas considerably larger than the sum of those already developed and under development.

The system is most efficient from the point of view of operation and is unusually well adapted to furnish the necessary supply of water of a superior quality.

It is a lasting tribute to the ability and vision of those who conceived its development and to the men in charge of the actual work of construction from 1846 to the present time.

THE RELATION OF THE METROPOLITAN WATER WORKS TO ITS MEMBER COMMUNITIES.

BY DAVID A. HEFFERNAN.*

[*Read September 29, 1931.*]

At the time this Association was organized fifty years ago a considerable part of what is now the Metropolitan Water District, and at present supplied by the water works of that name, received water from local or nearby sources, a few of which were municipally owned. The growth of the communities had by 1895 reached a point where the various sources were being overtaxed in several instances, and the increase of population upon watersheds was resulting in a deterioration of the quality of water from some of them. The movement for a water works which might properly supply Boston and those of its suburbs within a radius of ten miles of the State House gained strength and culminated in the formation of the Metropolitan Water Works substantially as it is today.

Former Sources of Supply.

At that time all of Boston, with the exception of Charlestown, having a population of close to half a million, was being supplied with water from the Cochituate Works, taking water both from Lake Cochituate and from the Sudbury River, in addition to some smaller reservoirs in the vicinity. Realizing the inadequacy of its source of supply, Boston was at the time developing the Sudbury watershed for future needs. It was expected that this source would be capable of being improved in order to furnish a more satisfactory grade of water.

The Upper Mystic Lake furnished a supply of water controlled by the city of Boston for the Charlestown district; from this source, water was also sold to Somerville, Chelsea, and Everett. Although the year 1894 was not excessively dry, the lake level was lowered 12 ft., notwithstanding that Charlestown was supplied several months from the Cochituate Works. This created the possibility of sea water seeping into the lake and rendering the water unfit for use. In the case of this source, as in that of several of the others to be mentioned, the fairly large population living on the watershed made its value as a potable water questionable.

Newton, with a population of about 28 000, was at that time the largest community in the state supplied with ground water. The works consisted of a collecting system along the banks of the Charles River in Needham, from which the water was pumped to filter into a covered

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gallery. The quality was considered excellent, and the need of Newton entering the Metropolitan system was not considered essential.

Spot Pond, which later became a distribution reservoir for the Metropolitan system was used jointly by Medford, Melrose, and Malden, having a combined population of 57 000, each city being permitted to use one third of the pond's storage. During dry spells the pond had been lowered 12 ft. below high water. In addition to this source, Malden had wells in the vicinity of Maplewood, a section of Malden, the water from which contained a considerable amount of mineral matter and was quite hard. Melrose in addition to drawing water from Spot Pond had a further supply which was purchased from a private water company, this source being from wells in the vicinity of Spot Pond Brook. The hardness of the water obtained from the auxiliary supply together with the large population on the territory from which the water was derived, made the quality of the water somewhat unsatisfactory. A temporary supply for Medford was obtained by pumping water from three small streams south of Spot Pond; these included Wright's Brook. When sufficient water flowed in these three streams, a temporary pumping station lifted this water into the supply main. While the quality of this water was good, the advisability of developing it as a future supply was questionable.

In 1888, Quincy supplied its population of 22 000 from a storage reservoir on Town Brook in Braintree. This source permitted the abandonment of one or two wells which had previously supplied this city. The presence of piggeries on this watershed and the fact that it included much swampy land, giving the water a brownish color, both contributed to criticism of its quality. Although the watershed contained a comparatively small population, it was believed that the quality of the water might be greatly improved.

Hyde Park (which was later annexed to Boston) and Milton, having a total population at that time of 18 000, were supplied by the Hyde Park Water Company, Milton being supplied by way of the Milton Water Company which purchased its water from the first-named company. Wells near the Neponset River, only a short distance above the thickly settled portion of Hyde Park, were the source. The Neponset River at that time was a highly polluted stream. The source of supply, to say the least, was regarded with suspicion, and it was recommended that it be abandoned as soon as a better supply could be obtained.

The Wakefield Water Company used Crystal Lake for its source. In addition to supplying that town, this lake was used to furnish water for Stoneham. The water was practically colorless and was of satisfactory quality in spite of a large population on the watershed. It was felt, however, that an adequate supply for future needs could be obtained at least as cheaply through a Metropolitan system as by developing local sources.

Brookline obtained its water from the ground on either side of the Charles River in Dedham and West Roxbury. The water so obtained

was considered of excellent quality, and an additional supply was not believed to be necessary for a number of years, which has proved to be the case.

The Revere Water Company obtained ground water from two sources, one in Revere and the other in Saugus and supplied communities of 11 500 in Revere and Winthrop. The water from the Revere wells was always hard, possibly due to their location near the sea, indicating that some sea water found its way into the wells. The Saugus wells, however, furnished water of good quality, but could not be developed for future needs.

Watertown and Belmont, which at that time had a combined population of about 10 000, were supplied by the Watertown Water Supply Company. Wells and a filter gallery near the Charles River in Watertown constituted the source. That part of this water which came from the filter gallery was of excellent quality, while the remainder showed the presence of iron and manganese; it was nearly free from bacteria. An additional supply could not have been obtained locally at a reasonable cost.

Arlington's supply came from a storage reservoir near Lexington; at the time consideration was given to turning water from Great Meadow into the reservoir. Water from the reservoir was very unsatisfactory for drinking, having a disagreeable taste. That part of the water which came from a filter gallery was more satisfactory although its purification by filtration was far from complete.

Swampscott and Nahant received water from the Marblehead Water Company. Wells in Swampscott near Stacys Brook and additional wells about half a mile away became affected by the infiltration of sea water and contained much mineral matter, although the water was considered pure.

Wells at the edge of a meadow near Vine Brook in Lexington supplied that town. The quality was considered good, but the development of a local supply for future needs was not feasible.

As a result of the study made at that time the Wachusett Reservoir was constructed on the Nashua River. An aqueduct which delivered this water to the Sudbury watershed was built, purchase of the existing Sudbury and Cochituate reservoirs and aqueducts, owned and operated by the Boston Water Department, was authorized, and Spot Pond was put in service as a low-pressure distributing reservoir. As a result seven cities and six towns formed the Metropolitan Water District, established in 1895. The cities were Boston, Somerville, Everett, Malden, Newton, Chelsea, and Medford. The towns were Belmont, Hyde Park, which was annexed to Boston in 1912, Melrose, Revere, Watertown, and Winthrop. As local conditions made it practical or necessary, other municipalities joined the district as follows: Quincy in 1897, Nahant 1898, Arlington 1899, Stoneham 1901, Lexington and Milton 1903, Swampscott 1909 and Brookline 1925.

These communities at present supply their entire population with

Comparative Statistics Relating to Cities and Towns in the Metropolitan Water District.

Municipality.	Population.	Per Capita Consumption. g.p.d.	Valuation per Capita. $	Cost of Water per 100 cu. ft. c.	Services per Mile of Main.	Water Debt per Service. $	Water Debt per Mile of Main. $	Hydrant Rental $	Annual Minimum Charge.[4]	Charge for Excess Water per 100 cu. ft. c.[5]
Arlington	36 650	54	1 580	6.40	87.9	40	3 510	None	10	23 to 15
Belmont	22 070	59	1 670	6.38	79.8	35	2 850	None	10	15
Boston	781 270	118	2 500	5.95	108.3	5	560	None	10	18.4 to 10.5
Brookline	47 730	98	3 470	7.20[1]	67.4	49	3 270	None	..	18
Chelsea	45 740	78	1 240	5.44	122.8	21	2 560	2 492[3]	6	13
Everett	48 740	102	1 480	5.35	122.0	16	1 980	None	6	12.5 to 10
Lexington	9 550	66	2 010	6.91	40.4	103	4 180	15[2]	15	30 to 18
Malden	58 350	62	1 210	5.77	97.6	3	310	None	8	18 to 14
Medford	60 320	56	1 280	6.01	101.7	39	3 950	None	8	20 to 12
Melrose	23 320	70	1 500	5.61	88.3	20	1 730	20[2]	9	20 to 15
Milton	16 610	52	2 060	7.39	52.7	96	5 050	35[2]	16	25
Nahant	1 660	119	3 480	6.85	90.0	62	5 550	None	..	33⅓
Newton	65 890	76	2 320	6.32[1]	75.6	24	1 850	15[2]	9	25 to 12
Quincy	72 580	76	1 910	6.32	89.9	44	3 930	13[2]	17	23 down
Revere	35 800	62	1 160	5.66	95.0	43	4 130	None	10	15 to 11¼
Somerville	104 150	90	1 140	4.76	125.0	None	None	None	6	15 to 8
Stoneham	10 110	68	1 280	5.53	72.3	12	860	None	10	30 to 13
Swampscott	10 420	78	2 700	6.15	86.2	27	2 290	1 000[3]	10	25
Watertown	35 380	61	2 170	6.21	83.7	17	1 420	None	10	25 to 13
Winthrop	16 890	71	1 500	5.71	55.0	18	1 007	15[2]	12	18 to 16

[1] Estimated Cost, if all water were taken from Metropolitan System.
[2] Per hydrant.
[3] Total.
[4] Quarterly and semi-annual charges have been placed on annual basis for simplicity.
[5] Only high and low steps are listed, omitting intermediate steps.

water from the Metropolitan Water Works with the exception of Newton and Brookline, which still operate their local plants and use the Metropolitan supply only at times or in part.

Present Operating Features.

Although all of these cities and towns are supplied from the same source, local conditions and individual problems operate to cause them all to function in different ways resulting in a number of varied systems, some of which will be discussed.

The statistics assembled in the accompanying table or referred to in the text for these cities and towns were derived partly from information obtained from the office of the Metropolitan District Commission, partly from questionnaires and partly by interview.

The principal sources of revenue of a self-supporting water department are:

Water rates (including meter rental).
Service installations.
Hydrant rental.
Miscellaneous jobbing.

Out of this income the department should be able to care for installation of new mains and for general operation and maintenance expenses. In some cases main installations are bonded. In this event the bond retirement expense and interest on bonds should be paid out of income.

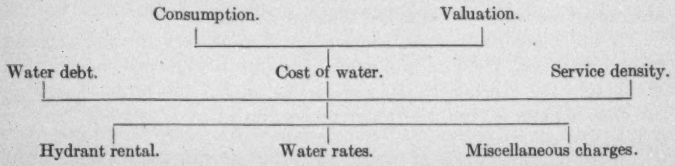
From questionnaires sent to all cities and towns in the Metropolitan District it appears that not all departments know whether or not they are self-supporting. They request a certain appropriation covering their needs and are not always certain whether their income is sufficient to offset their expenditures.

One item on the questionnaire was: "Are all operating and bond expenses and the Metropolitan Water Assessment paid from water-department receipts?" About half the departments did not reply; these were visited. One town official in the District, upon being visited, stated that appropriations for main extensions were not received from the town. A few days later the questionnaire, which had been delayed, was received with the information that in 1930 an appropriation of almost $100 000 was made for this purpose. In this instance and from conversations in other cities and towns the author is lead to believe that in several cases the water departments are not certain whether or not they are on a self-supporting basis. One town in fact did not know how many miles of mains they had in service. Another claimed to account for 98 per cent. of its water.

In Milton, the Commissioners feel that each branch of the service should provide income enough to bear the expense it incurs.

Certain factors applying to all communities may be used as a fair comparison to show how conditions vary and what may result from the difference in these conditions.

These factors may be set up in this manner



In the Metropolitan Water District the consumption and valuation, considered together determine the cost of water. Water Debt is a result of outgrowing old pipes and increase in population. These two main factors, cost of water and water debt, together with operating costs, determine rates, which should vary with service density.

It may be well to mention here the method followed in computing the annual Metropolitan Assessment. First the Metropolitan District Commission determines the amount of money it will need for sinking funds, retirement of serial bonds, interest, maintenance, and improvements. The total valuation and consumption of water in each municipality of the district are obtained and the ratio of valuation and consumption of each in direct proportion to the total for the District is then determined and applied to the financial requirements, one third in proportion to valuation and two thirds in proportion to consumption.

The Legislature in 1927 authorized the issuance of $65 900 000 in bonds to provide for the so-called Ware and Swift River projects, which when completed will provide an additional source of supply for the District. About one quarter of this construction has been completed, and the material increase in the individual assessments has been a matter of concern to some cities and towns. For instance, Milton's assessment has increased 54 per cent. since 1927.

It may be seen from the table that Milton paid 7.39 cents per 100 cu. ft. last year. Brookline and Newton's costs are rather high, but are based on figures obtained from the Metropolitan District Commission as estimates of what these two municipalities would pay if all of their water was supplied by the Metropolitan District Commission; their actual costs are probably materially less. Nahant and Lexington pay rather high rates. Nahant's valuation per capita is the highest in the District as is its consumption, due in both cases to its summer population. Densely populated sections, with a low valuation per capita, such as Somerville, Chelsea, and Everett, obtained their water at a lower rate. The fact that Milton is purely a residential town and that a considerable

number of its townspeople work during the day outside of Milton contributes to a low consumption. Manufacturing centers such as Boston, Everett, and Somerville, have a high per-capita consumption.

To see how this works out, let us take a city with a relatively high consumption and comparatively low valuation. This enables the city or town to get its water at a cost less than the average.

If this place has a small water debt, if its streets are well supplied with mains, and there is not much need for new developments, thus eliminating the expenditure for new mains, and if the ratio of services per mile of main is high, the water takers benefit by a very low rate for water.

If the use of water is small in a town of high valuation; if it has been necessary to lay mains in thinly populated areas to supply widely separated houses; and growth has made necessary reinforcement and improvement programs, entailing a considerable debt, such a community must provide for more revenue through water rates or direct appropriation.

One gage for comparing water rates is the density of population and this may be fairly obtained from the table by reference to the column headed "Services per mile of main." It should be understood that in densely populated areas the number of services per mile of main will be considerably higher than in the sparsely settled sections. Only one town, Lexington, has fewer services per mile of main than Milton, and it will be noticed that Lexington has a high water rate.

The distinct relationship between population and rates is reflected in the table. Chelsea, Everett, and Somerville should be able to sell water at a lower rate than Lexington, Milton and other smaller places, which are less densely populated. It is interesting to note, in passing, that Milton, with a population of 16 610 has 3 981 services as compared with Brookline's population of 47 730 and 7 677 services. In other words, Brookline's population is nearly three times that of Milton's and it has less than twice as many services. This is probably due to the fact that Brookline contains many apartment houses.

A study of the water rates shows great variations. In different cities and towns, billing is done, quarterly, semi-annually and annually, and the rates vary in the minimum charge from $6.00 a year in Everett and Chelsea to $3.75 a quarter in Lexington; Quincy makes a minimum charge of $17.00 for single and $21.00 for two-family houses annually. The charges for excess water are shown in cents per hundred cubic feet, and in municipalities having step rates only the high and low charges are shown for the sake of brevity. It may be noted that residential communities such as Milton, Belmont, Nahant, and Swampscott have but one rate for excess water. However, most of the cities and towns in which industries, truck farms, and similar activities require great quantities of water, have found it necessary to sell water cheaper to those using considerable amounts. Swampscott, I believe, is the only member of the system making

a charge for meter rental, which varies from $1.00 to $15.00 a year, depending on the size of the meter.

Milton receives a greater hydrant rental than many other departments in the District and is not entirely satisfied that it is sufficient now. The term "hydrant rental" is misleading in that it is not as broad as the service it renders. It does not take into consideration distribution capacity. During the past seven years, Milton has replaced a considerable number of mains which were entirely adequate for domestic requirements but which were not large enough to furnish sufficient water for fire-fighting. The differential in cost of mains above that needed to supply domestic uses should be considered, since a hydrant connected to an inadequately sized main cannot deliver its full capacity.

A great variety of procedure of charging for service installations was encountered. Nine departments make no charge for installing services from the main to the street line. Boston, however, lays the service pipe only as far as the property line, making a charge for a $\frac{5}{8}$-in. service of $55 and for a $\frac{3}{4}$-in. service of $60. In Belmont all services over one inch in diameter are billed at cost plus ten per cent. Malden, Nahant, and Somerville have a flat charge of $30 or $35 for installing domestic services in the street. Winthrop attempts to treat property owners on both sides of the street alike, charging for one quarter of the street work and for full costs inside the line. Medford, Newton, Revere, and Stoneham charge for the entire cost of the service. That part of the service installed inside the property line is charged for in several different ways; some making a flat charge per foot and some doing the work at cost. If the installation in the street is made free, then the cost of it must be borne by the revenue from another branch, probably water rates. A service installation is useable only in the location where it is installed; it cannot be used for supplying another piece of property. In mentioning that service work is done at cost it should be remembered that this may mean "invoice cost," "job cost" or "actual cost." In Milton the entire service is charged at invoice cost plus overhead, to cover supervision and other expenses. As a result, the water takers are assured that the cost of service installation in the street is not paid for out of water rates. The experience Milton has had is probably similar to that of other Boston suburbs. Studies of the system of mains made individually by a competent firm of engineers and by the New England Insurance Exchange revealed several weaknesses due to two causes:

When Milton entered the Metropolitan Water System, the main connection with the supply pipes was at the opposite end of the town from that through which the supply entered when water was purchased from the Hyde Park Water Company. This had the effect of reversing the flow in the distribution system and left the mains below proper size in certain parts of the town; and the rapidly increasing population of the town during the past few years outgrew the original mains in certain sections.

These changes made necessary a considerable expenditure for mains in addition to those installed in new developments, and during the past seven years the major part of these installations have been bonded. Milton's water debt per mile of main is $5 050 higher than that of any community in the district except Nahant which has only ten miles of main pipe. To a lesser degree this is true of all the rapidly growing suburbs. A high relative debt means high carrying charges, and it will be noted that a large debt per service exists in those cities and towns which have the higher water rates. Self-supporting water departments must meet large carrying-charges on bonds and notes outstanding through rates or otherwise.

Water departments, if efficiently operated and supervised, may control their maintenance and operating expenses; they can control neither their cost of water, nor the growth of the community, which requires new main installations.

If a department is to be self-supporting, it must meet these expenses largely through water rates and hydrant rental, but the cost of other activities such as service installation should carry themselves.

FIFTY YEARS IN WATER WORKS PRACTICE.

BY CALEB M. SAVILLE.*

[*Read September 30, 1931.*]

Tempora mutantur, et nos mutamur in illis.†

Much water has "gone over the dam" in the fifty years since the founding of the New England Water Works Association, and the superintendents and engineers responsible for its inception, all with honorable records, have gone to their reward. Their work and the result of their efforts for improved water-supply service are imperishable. The chronicle of the march of water-supply work in the past fifty years can be little more than a summary of articles which are registered on the pages of the JOURNAL of this Association, placed there by masters of water-supply science.

This paper is and must be a composite of data supplied by many good friends, and it is with much regret that the author finds it impracticable to include all of the valuable data which have been so generously supplied.

In looking through the Transactions of the Association in its earliest meetings, one finds as subjects for discussion topics, a good many of which are of present day importance; among others: Service pipe, Materials, Size, etc.; The Filtration of Water; Weights of Cast-Iron Pipe;[1] ‡ Use of Tanks for Supplying Water to Closets and Hot Water Boilers; Flushing Street Mains; Materials for Street Mains;[2] etc.

In the address delivered at the dinner to the American Water Works Association in 1885, President George A. Ellis stated,[3] that while "a few years back only our large cities had a water supply worthy of the name, now every town and village is moving for such a supply under pressure. Already there are reported over 1 000 water works in America," of which more than one half obtained their water by pumping. Also "Everyone of our large coast cities from Washington to Boston, with the single exception of Baltimore, is already moving for an increased supply."

In his address to the New England Water Works Association at their Boston meeting, Governor George D. Robinson stated[4] that "during the 215 years previous to 1885 there were but ten acts of the Massachusetts Legislature governing and restricting the use of water." If so found in the ancient state of Massachusetts, it is probable that this situation was indicative of similar conditions throughout the country, and the multiplicity of laws now on the statute books of all of the states is a reminder of the activities of water-works men in the past half century.

In 1885,[5] the cities of Concord, Manchester, Nashua, Lowell, Lawrence and Haverhill took their water supply directly from the Merrimack

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†Times change, and we change with them.
‡All numbered references are listed at the end of this paper.

River, which was even then badly polluted by the drainage of the cities and towns above the intake works.

At the annual meeting of this Association in 1885, Desmond FitzGerald[6] said that he had that day sent 27 m.g. of water to the city of Boston, also that the city of Providence had no public supply of water until 1870, although a city of 50 000 inhabitants, and that the city of New York was then "pushing to speedy completion one of the largest, if not the very largest, water-supply systems of the world, involving the building of the highest dam the hand of man has ever undertaken, and an aqueduct 14 ft. in diameter to carry 300 m.g. of water per day." In September, 1930, the city of Boston received an average of 96 860 500 gal. per day. The Hoover Dam, now under construction near Las Vegas, Nevada, is 730 ft. high as against the 262-ft. Quaker Bridge Dam referred to by Mr. FitzGerald.

Beside the wonderful progress that has been made in construction and material matters, there also must be considered the coming of State Regulatory Commissions with power to supervise both the quality of the water furnished and the charge that can be made for it together with methods of financial operation. The remarkable reduction in the typhoid fever death rate and the decrease in fire-insurance premiums are major indices of the progress in water-supply work in the past forty years.

It is interesting to note that the founding of the New England Water Works Association is practically coincident with the beginning of attention to water-supply distribution and the general improvement of water-supply work. It is stated that in 1880 there were only about 600[7] water supply systems in this country, about half of which were under private ownership. In 1924, it is estimated that there were about 10 000 public and private plants in service, while in 1830, or 100 years ago, there were only 46 plants of record.

The conception in the minds of the founders of the New England Water Works Association was the desire of serious men to contribute for the common good their personal knowledge and experience in their particular calling. I believe it to be a fact, that, although a semi-technical association, its contributions to water-supply science have not been excelled by any other body in the world. The pages of the JOURNAL of this Association are replete with articles from the water-supply engineers of the country, and it would be hard to find one of any prominence who has not contributed both of his knowledge and active support.

About 1890, a great forward step seems to have been taken in modern water-works practice in this country, and a review of water-works history discloses that outstanding work was done about this time in matters pertaining to pumping machinery, purification of water and the distribution of water for domestic and fire-protection purposes. While a great deal of credit for development must be given to the makers of water-works equipment, it must not be lost from sight that such men as Forbes, Richards, Haskell, Hall and other practical water-works men, looking further ahead

than being mere foremen of gangs, gave the suggestions and stimulant for improvement of service, without which there would have been no such business as exists today, and that, in most cases, the beginnings of what are now flourishing industries had their start in the shop of some water-works superintendent.

The real science of water-works design and operation came into being not much over forty-five years ago, as the result of the studies and work of such men as Fteley, Stearns, Sedgwick, FitzGerald, Metcalf, Brackett and others who were earnest and enthusiastic members of this Association.

The experience of Boston in the development of its water-supply system is an example of what most municipalities throughout the country have encountered during the past fifty-year period. Following the introduction of the first publicly developed water supply in 1848, when water was introduced from the Cochituate supply, came the Sudbury additions of 1878–1894, which, when combined with the Cochituate Supply, gave an estimated yield of 65 m.g.d. In 1880, the requirement of the city of Boston was 36 m.g.d.; in 1890, it had increased to 47 m.g.d.; in 1894, water was being used at a rate of 46.6 m.g.d. In 1930, the consumption of this city had risen to about 97 m.g.d., with an estimated per capita use of 118 gal. The experience of the Boston Metropolitan District is given merely as an example of the increase in water use generally in the past fifty years.

These works, together with those of local water-supply developments in the surrounding towns, became inadequate for the demands of the growing Metropolitan District, and, in 1893, legislative authority was sought for the development of additional sources on the Nashua River at Clinton. This led to the development of the Wachusett Supply with an estimated daily capacity of 111 m.g.d. With the completion of this work, it was estimated that there was a gross supply available for the District of about 173 m.g.d.

But "times change, and we change with them," and with the encroachments on watershed areas and the demands for different quality of water, older supplies have been abandoned, new ones sought and sources hitherto deemed unavailable pressed into service. Such tremendous requirements for water have forced the use, in many cases, of sources and methods which, at the beginning of our period, would have been considered neither available nor desirable for development. Absence in the south or middle portions of the county of upland gravity sources such as have been mostly available in the east and west portions have forced the use of water not suitable in its ordinary state for domestic supply.

To meet these demands, necessitating the use of water from sources previously unconsidered because of character and condition, remarkable strides have been made in water purification, led by such men as George W. Fuller and Allen Hazen, whose early training included laboratory experience gathered with the Massachusetts State Department of Health, under the urge of such men as Dr. Drown, F. P. Stearns and Hiram Mills.

With the introduction of new and convenient service, the matter of excessive use and waste did not at first receive much notice, but as costs of supply increased and quality of water available, in many cases, deteriorated, it became evident that some method of conservation of water must be found; hence the introduction of meters for measuring water used, and paying, therefore, in proportion to that use. As an example of the efficiency of that method for reduction of waste, recourse may again be had to the experience of the Boston Metropolitan District, with a consumption of 126.5 g.p.d., per capita and 20.5% services metered in 1908 and a consumption of 98 g.p.d. per capita and 98% services metered in 1930.

Cast Iron Pipe.

Pipes of cast iron came into use in this country early in the 19th century, the first authenticated installation, in Philadelphia in 1807, still being a part of the distribution system of that city. This pipe was made in England and designed for bell and spigot joints with lead fillings.

Up to about eighty years ago, iron pipes were uncoated, and, with some waters, became so badly tuberculated that carrying capacity was very much reduced. This trouble was greatly lessened by coating the pipe with a coal-tar preparation, suggested by Dr. Angus Smith in 1847, and cast iron then became a standard material for water pipes. While this coating was very satisfactory, when made and used according to original formula, the exigencies of trade in the United States developed coatings which were less and less efficient both in material and in application.

Within the past ten years, the interior deterioration of cast-iron pipes had become such a major problem that it was plainly evident that either a proper coating must be found and used, or else other materials might supersede cast iron to a considerable extent. Here, as in other cases, the urge of competition rather than the desire for improvement itself seems to be the incentive for advancement in this art. Be this as it may, both manufacturer and user are now coöperating to the end that a better product may result, and, already, there are several coatings with diversified methods of application which seem to offer real help, if not correction. Among these may be mentioned cement mortar, bitumastic enamel and combinations of other materials.

Even as late as a quarter of a century ago, the making of cast-iron pipe was considered as a distinct craft, the art being handed down from one generation to another or through apprenticeship. The "old timer" knew by instinct the correct metal mixture, right molding-sand consistency and other characteristics necessary to make a good casting. Metallurgical, chemical and physical knowledge was not considered an essential at this time and was of little interest to the pipe maker of fifty years ago. The earliest known cast-iron pipes were cast in lengths of about one meter, then six feet, nine feet, twelve feet and now sixteen to twenty feet as desired.

Pipes were first cast horizontally, usually with a thin place on one side due to "floating" core, and all the impurities on the thin side; then "on the bank," *i. e.*, at an angle in an effort to avoid these defects; then the flasks were placed vertically and the cores centered, this being a great advance and producing a much better pipe than formerly.

At the present time, vertically cast pipe is rapidly giving place to centrifugal casting, and with this latest development, pipe making has been so revolutionized that methods and equipment representing most up-to-

FIG. 1. — SHAVING OF SAND-SPUN PIPE.

date practice ten years ago are now being rapidly displaced. Two methods are in use in casting pipe centrifugally: (1) The so-called De LaVaud process, which uses a rapidly revolving water-cooled metal jacket as a form to be plastered with the hot metal poured in from a spout inside the jacket; (2) the so-called "sand spun" or "mono-cast" process, where the mold is lined with sand and the chilling effect of the water-cooled jacket is avoided. Pipes of as large as 24 in. in diameter are now being successfully turned out by the centrifugal processes.

Many other improvements in foundry practice have accompained the changes in pipe casting. Among them are pneumatic ramming of the flasks instead of hand ramming, automatic sand and dust control, electric furnaces for positive control of iron mixtures, chemical and metallurgical laboratories and lighting and ventilation of shops. The real advance in pipe making by the centrifugal process properly done is the production of

a pipe materially reduced in weight over the old "pit-cast" pipe with increase of strength, and having greater bending ability and resilience than was formerly obtainable. Much space has been given to this matter of pipe manufacture, because, after all, it is perhaps the most important part of any water-works system.

Through the courtesy of Mr. Walter Wood of R. D. Wood & Company, there is shown in Figure 1 a full sized "shaving" about 30 in. long, cut from a "sand spun" pipe, and coiled exactly as shown in the cut. This figure is to illustrate the character of iron in pipes cast by centrifugal processes in sand lined molds as compared with "chips" from an ordinary pit-cast iron pipe.

As to cost of cast-iron pipe, the following table speaks for itself, and it is sufficient to point out that notwithstanding the vast sums expended latterly in the production and improvement of cast-iron pipes as well as the advance, both in cost of labor and freight rates, the cost per ton today is about the same as it was fifty years ago:

COMPARISON OF CAST-IRON PIPE PRICES PER LINEAR FOOT.
"PIT-CAST" AND "CENTRIFUGAL."
1931 QUOTATIONS.

Size. Inch.	"Pit-Cast." Class C — A.W.W.A. $35 per ton.	"Centrifugal." Class 150.
6	$0.63	$0.46
8	0.91	0.65
12	1.60	1.39
16	2.49	2.30

To compete with the prices quoted for "centrifugal" pipe, "pit-cast" would have to sell for about $25 per ton for 6-in. and 8-in. sizes, $30 per ton for 12-in., and $32.50 per ton for 16-in. In 1931, pig iron was quoted at $15 per ton, and cast-iron pipe was quoted at $25 per ton in 1916. There has been a broad spread in prices of cast-iron pipe during the fifty years last passed; in 1882, $35.68 per ton; in 1898, $15.48 per ton; in 1920, $75.00 per ton; and, at present, $36.00 per ton. During the past fifteen years foundry-labor wages have increased at least 300%, and freight rates have been doubled.

Up to about fifteen years ago, the jointing of water pipes was made with lead poured into the space between spigot and bell of contiguous pipes and consolidated with caulking irons in the hands of experienced men. Lately, jointing compounds have been used, which, when poured into the joint in a liquid state, harden to a water-tight joint without further attention. This method obviates the necessity of bell-hole excavations at the joints and does away with the skilled caulking labor necessary with the lead joint.

Up to about thirty years ago, there was no standard in this country,

either in the shape of bells of pipe and castings, or in the thickness of pipe walls. Most foundries had their own patterns, which differed one from another, and many of the larger cities also had their own requirements in these matters. In 1902, at the special instance of Dexter Brackett, Past-President of this Association, and, at that time, Engineer and Superintendent of the Boston City Water Works, the New England Water Works Association adopted a standard set of specifications for pipe and special castings; six years later, similar action was taken by the American Water Works Association. This latter set was the outgrowth of the six years' experience with the earlier set and has since become a standard throughout the country.

The use of wrought iron as a competitor with cast iron in the larger sizes began just prior to the founding of this Association. The first riveted wrought-iron pipe installation in the east was that of the city of Rochester in 1873–1875. With the development in the steel-plate industry, a number of long lines of large-sized pipe were laid. Among the earlier installations were those at Rochester in 1892 and at New Bedford and Cambridge, Mass., in 1895. The New Bedford pipe is still in service but badly corroded in spots and with some of the pittings fully half-way through the shell of the pipe. Present day practice has mitigated, if not overcome some of these objectionable features of steel pipe, by interior coating and heavy outside wrapping of hessian cloth soaked in bitumen to an accumulation of about $\frac{1}{4}$ in. or more.

Aqueducts and Conduits.

So far as supply pipe-line installation goes, it appears that tremendous strides have been taken in the past fifteen years in the development of materials that avoid or lessen troubles incident to the use of cast iron, so that cast-iron pipe now has several well recognized competitors. For distribution work, however, and for sizes of pipe 24-in. and less in diameter, no material has yet come into use that can take the place of cast iron.

Within the past quarter century, the introduction of steel and reinforced concrete pipe for conduits of moderate size has superseded the materials of earlier years. Examples of this later method of construction are found in the 7-ft. conduits of the North Jersey Water Supply Commission, 1929, one section of reinforced concrete, built by the Lock Joint Pipe Company, the other of Lock-Bar steel pipe, coated inside and out, built by the East Jersey Pipe Company.

The use of steel pipe for major water-works projects dates back about forty years. Riveted steel plates were first used in its fabrication. The losses by friction in this pipe were a considerable detriment to its use, and, in 1904, Lock Bar pipe was brought out and at once very favorably received as a distinct advance in pipe work. Some ten years later, hammer-welded pipe was introduced, but was never particularly popular with water-works engineers. About six years ago (1925), electric welding of the longitudinal joints became a factor in the pipe market and its use has since been quite

universal. At the present time, the tendency is to use greater thickness of steel plate than was the custom in the earlier years, and, nowadays, flange steel is being specified in place of tank steel formerly used. As steel plate is particularly susceptible to corrosion in some soils and waters, protective coatings have been devised that seem to be quite efficacious in combatting this trouble.

A considerable advantage that steel pipes have over those of cast iron in

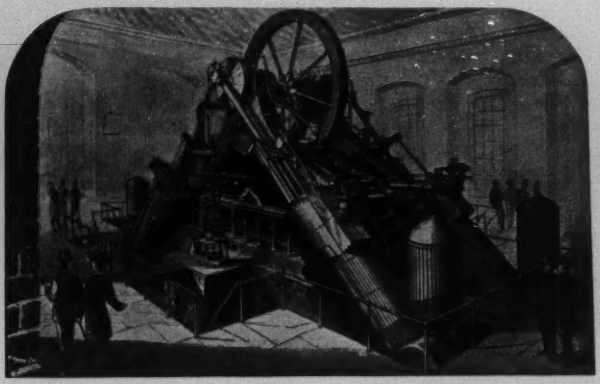


FIG. 2. — HOLLY QUADRUPLEX PUMPING ENGINE.

the larger sizes is first cost, ease in transportation, and less liability of breakage in service. The matter of disastrous breaks in city streets with resulting damage to property and annoyance to traffic has become of much importance in such localities, and pipes are now being sought which will decrease, if not wholly obviate, a trouble which has become more frequent with the advent of heavy trucks moving at rates of speed sufficient to set up vibrations dangerous to pipes with brittle characteristics and joints which "give."

At about the same time that steel plate was beginning to be recognized as a material for water-conduit construction, reinforced concrete (1906) also was receiving attention as a competitor, and steps were being taken to develop a pipe of reinforcd concrete that would carry water under pressure. Today standard practice builds up a thick covering of reinforced concrete with a welded steel cylinder, for the higher pressures, and there seems every reason to believe that a permanently water-tight structure has been obtained, which is safe and satisfactory under fairly high pressures.

Within the past ten years, pipes of reinforced concrete with diameters of thirty inches and more have been built for supply lines in a large number of places with much satisfaction of service. Pipes of this material seem to

combine the advantage of steel, the durability of cast iron, and ability to exceed both by maintaining original capacity of flow with comparatively low installation costs.

Pumps and Pumping Engines.

The advance in pumping machinery and its design has been, perhaps, more spectacular than that in any other branch of water-supply work. So

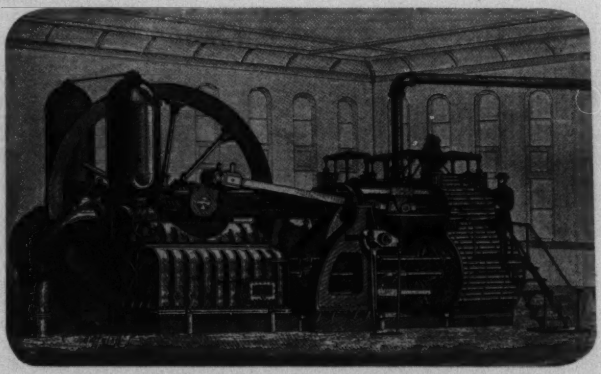


Fig. 3. — Holly Horizontal Compound Pumping Engine.

complete have been the changes that present-day pumps and their engines have little in common with those in use a half century ago.

Prior to 1870, there were comparatively few pumping engines at work in this country, and these were of simple as well as inefficient type. In 1872, the Holly Quadruplex pumping engine was placed on the market as a part of the combination of fire-protection and domestic service that came to be known as the "Holly" system. This engine marked a tremendous stride forward and was the prototype of the modern pumping engine developed in this country. This pumping engine of the crank and fly-wheel type is illustrated in Figure 2, reproduced by the courtesy of the Worthington Pump and Machinery Company. It was built with a capacity of from 2 to 6 m.g.d. and became very popular. It was so constructed that it was possible to operate it either as a simple Quadruplex engine or as a compound unit by exhausting the steam from one high-pressure cylinder into the three other cylinders, thus providing for either high-pressure fire-protection needs or lower-pressure domestic service.

In 1882, a new design of pumping engine was brought out — the horizontal compound condensing type, the first installation being a 5-m.g.d. unit at Saratoga Springs, N.Y. Figure 3 illustrates the general appearance of

such an installation. Various improvements in design and efficiency followed one after the other up to the improved Holly vertical triple-expansion pumping engine developed about 1897, marking continued progress in increase of fuel economy and decrease of cost of plant and operation. Three 35-m.g.d. units of this type were installed about 1900 at Chestnut Hill Station of the Metropolitan (Boston) District and are now in service on

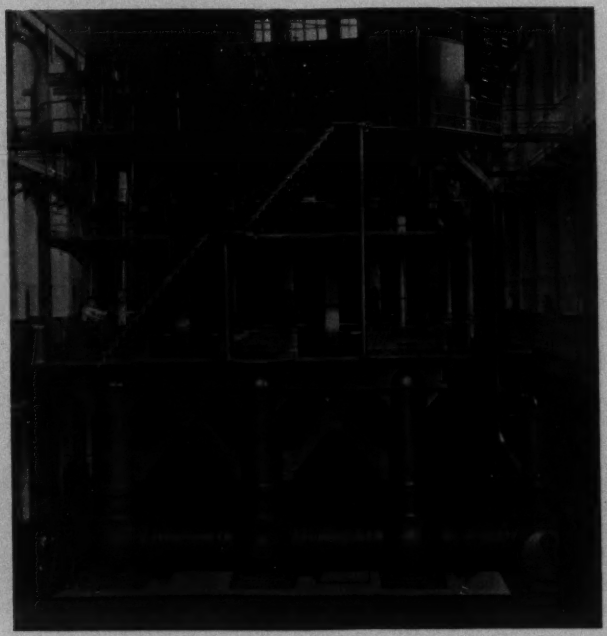


FIG. 4. — VERTICAL TRIPLE EXPANSION PUMPING ENGINE, MILWAUKEE, WIS.

contract trial. At this same station, a fourth unit of 40-m.g.d. capacity, used for high-service work, and built by the same makers, gave a duty on contract trial of 176 066 000 ft.-lb. per 1 000 lb. of steam with super-heat of 15° F. and a gage pressure of 151 lb. per sq. in. at the throttle valve. In 1914, a 17-m.g.d., triple-expansion high-service pumping engine installed by the same makers for water service at Cincinnati, Ohio, developed 182 042 000 ft.-lb. per 1 000 lb. dry steam. In 1927, a 22-m.g.d., triple-expansion unit (Figure 4), installed by the Allis-Chalmers Manufacturing Company at the Riverside Pumping Station of the city of Milwaukee, on official duty test developed 204.6 million ft.-lb. per 1 000 lb. of steam,

steam pressure 200 lb., super-heat 100° F., head 280 ft. The development of this type of pumping engines has brought about a machine of remarkable mechanical efficiency with a difference in some cases of not over five per cent. between indicated and water horse-power.[8]

There is a wide spread between the 12-m.g.d. pump of the vertical compound beam type installed by the Allis-Chalmers Manufacturing Company for the city of Milwaukee in 1880 and the 22-m.g.d. pump with its triple-expansion engine installed in the same city by the same company in 1927. Both of these installations were representative of best mechanical

FIG. 5. — THREE-STAGE, TURBINE-DRIVEN CENTRIFUGAL PUMP, PENNSYLVANIA WATER CO.

output of their day, the earlier plant developing 105 million ft.-lb. per 100 lb. of coal, and the latter plant 204.6 million ft.-lb. per 1 000 lb. of steam. It is interesting to note the gradual increase in steam pressure used in these engines from 80 lb. per sq. in. in 1880 to 125 in 1890, 150 in 1900, 175 in 1906 and 200 in 1927.

At the present time, the efficiency and reliability of the modern triple-expansion pumping-engine is preëminent among mechanical developments. Its high cost of plant and operation, however, have led to the development of other types of pumping machinery.

Some sixty-five years ago, a centrifugal pump is said to have been designed and used by a white farmer and his negro helper near Baldwinsville, N. Y. This design was later purchased by Mr. Morris, Sr., founder of the Morris Machine Works, and developed by him and his son. At about the same time, other builders entered the field, until at present there are many reputable builders of centrifugal pumps in this country. As late as 1910, however, the centrifugal pump was considered mostly a type of low-cost pumping-equipment for large quantities under low head or small quantities under higher heads, when efficiency was not of much importance. The centrifugal pump has the advantage of less space, less attendance, less first cost, lower cost of foundations and a more simplified and conven-

ient form of drive. The urge for mechanical progress has now achieved most remarkable success in the development of this pump, coupled with the use of the steam-turbine drive and later the substitution of electrical energy for steam as a prime mover.

A score of years ago, the points in favor of this type of plant for municipal pumping-service caused it to receive very serious consideration in

FIG. 6. — RIDGEWOOD NORTH SIDE PUMPING STATION, BROOKLYN, N. Y.

competition with the crank and fly-wheel type of engines, and gradually increasing numbers have been sold as improvements were brought out and economy of performance increased. At the present time, geared steam-turbine-driven centrifugal pumping-units are probably giving from 25 per cent. to 30 per cent. better duty than they did in 1910, and now with high steam pressures and reasonable super-heat, nearly as high a duty is obtained as with the most economical type of crank and fly-wheel pumping-engines. A representative installation of this type of pumping equipment is that built by the Allis-Chalmers Manufacturing Co., for the Pennsylvania Water Company (Figure 5), a 16-m.g.d. pump driven by a 2 330-h.p. steam turbine and Falk Gears against 645 ft. head with turbine speed of 3 860 r.p.m.

Lately, the use of geared steam-turbine drive has been superseded by motor drive which has now received such prominence as to indicate the future trend in municipal equipment toward this means of operation. Some of the chief factors which have brought about this change are the present availability of high-voltage electric current, the reduction in cost of electric

current, the increased reliability of electric service, the lower first cost of electric pumping equipment and the fewer number of station attendants required. All of these factors together with reduction in cost are applicable in varying degrees to both large and small plants. A typical illustration of this method of pumping is found in the plant shown in Figure 6. Here are four 25-m.g.d. Worthington single-stage centrifugal pumps, each driven by a 1 200-h.p. 720-r.p.m. Westinghouse motor against 175 ft. head, installed in 1931 at the Ridgewood North Side Station (Brooklyn) of the Water Department of the city of New York.

For purposes of general comparison, the following table is submitted, not as giving any specific figures from any plant whatsoever, but as a close estimate of what may be expected, taking the cost of steam for 1 000 lb. as 40¢. This figure, of course, varies according to local boiler plants and operating conditions, being considerably too low for smaller plants not economically operated.

COMPARISON BETWEEN
VERTICAL TRIPLE EXPANSION PUMPING ENGINE,
STEAM TURBINE DRIVEN CENTRIFUGAL PUMP,
MOTOR DRIVEN CENTRIFUGAL PUMP.

	Vertical Triple.	Steam Turbine Centrifugal.	Motor Centrifugal.
Capacity, m.g.d.	20	20	20
Life of Unit, years (used for depreciation)	40	20	20
Head pumped against, ft.	220	220	220
Steam pressure, lb. dry steam	180	180	..
Water Horsepower	773	773	773
Duty, million ft.–lb. per 1 000 lb. steam	178	138	..
Combined efficiency motor and pump	..	..	82%
Total lb. of steam per hour	8 600	11 100	..
K.w. per hour	..	..	704
Cost of steam per 1 000 lb.	40¢	40¢	..
Cost of current per k.w.h. (assumed)	..	..	¾¢
Electricity used per 24 hr., k.w.h.	..	..	16 896
Cost of steam per 24 hours	$82.56	$106.56	..
Cost of current per 24 hours	..	..	$126.72
Total cost of steam or current per year — 365 days	$30 134.00	$38 894.00	$46 253.00
Approximate cost of pumping unit delivered and erected	$210 000.00	$50 000.00	$15 000.00
Interest on cost of pumping unit at five per cent. annually	$10 500.00	$ 2 500.00	$ 750.00
Annuity for depreciation, based on life of unit at four per cent. compound interest	2 210.00	1 679.00	504.00
Maintenance and repairs	2 000.00	750.00	225.00
Cost of steam or current per year	30 134.00	38 894.00	46 253.00
Yearly cost of operation	$44 844.00	$43 823.00	$47 732.00

The general trend of advancement in pumping equipment for the smaller plants seems to have been through the following stages:

Triplex pumps belt-driven from steam engines.
Simplex or Duplex steam pumps.
Triplex pumps driven by electric motors.
Centrifugal pumps belt or steam-engine driven.
Centrifugal pumps steam-turbine driven.
Centrifugal pumps driven by electric motor and gasoline engines.
Triplex and centrifugal pumps driven by Diesel engines.

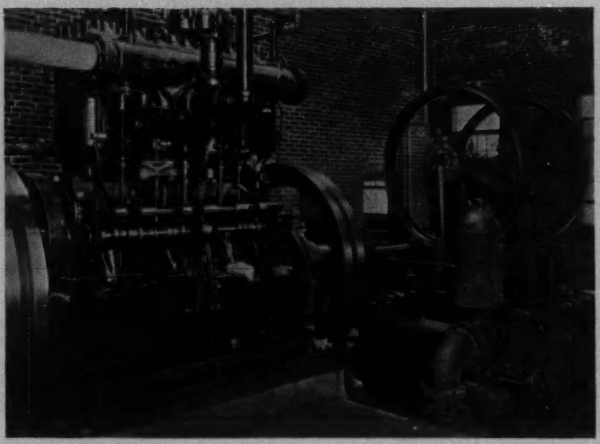


FIG. 7. — DIESEL-ENGINE DRIVEN TRIPLEX PUMP.

A typical Triplex pump plant with Diesel-engine drive is that installed by "Goulds Pumps" (Fig. 7).

The general trend in steam-pumping machinery at the present time has been toward the use of water-tube boilers with steam pressures from 300 to 600 lb. per sq. in. and a total steam temperature of around 700° F.

On account of high cost and larger space required, there is a drift toward steam-turbine-driven centrifugal pumps, two outstanding recent installations being the William Hale Thompson Station in Chicago and the Howard Bend Station at St. Louis. Several other large cities have installed electrically-driven pumping units, large plants of this type being found in New York, Philadelphia and Baltimore.

With electricity at one cent per k.w.h., the cost of pumping by this means compares favorably with best steam practice, and low first cost, small space required, ease of operation and minimum amount of labor

required are large factors in favor of electrical operation. On the other hand, a water system dependent entirely on pumping for its supply lays itself open to interruption of service due to accidents to electric power and transmission lines. The chance of these happenings may be minimized by duplicate lines and electric power plants, but that there is a chance of interruption of service with its conflagration hazard as well as annoyance and damage to consumers cannot be entirely prevented, and, at the present time, no precise move has taken the place of steam so far as reliability and continuity of service are concerned.

Dams and Reservoirs.

Comparison of the profiles of the New Croton Dam (1892), Ashokan Dam (1907), Wachusett Dam (1900), Nepaug Dam (1913) and Elephant Butte Dam (1912) shows that dams have been gradually growing higher as the years have advanced and more knowledge of materials and methods of placing has been gained.

In the endeavor to obtain lower costs, and, in some cases, to admit of building any structure at all, many different forms of construction have been employed, particularly within the past quarter of a century. Among these, in the masonry class, are cellular masonry dams, buttressed dams and multiple-arch dams. In the earth-fill dam, while profiles have changed very little, methods of construction have advanced considerably in the past fifty years. As previously noted, it is a far cry from the Quaker Bridge (N.Y.) design with its 262-ft. height, bedrock to crest, and stated by FitzGerald in 1885 to be "the highest dam that the hand of man has ever undertaken," to the Hoover Dam on the Colorado River, with its 727 ft. above bedrock, or, in the case of earth dams, from 1901, when a special commission of eminent engineers considering the New Croton Dam (N.Y.), advised against earth dams of over 70-ft. height, to the 245-ft. height of the Cobble Mountain Dam of the Springfield (Mass.) Water Works.

As an example of modern methods of coping with unsatisfactory foundation conditions, may be cited the Rodriquez Dam, Ambursen masonry type, near Tia Juana, with a fault in the work foundation, from which soft rock and broken stone were excavated to a depth of 150 ft., and replaced with concrete, then arched over and the dam built 187 ft. high above that point. Other novelties in dam construction at the time of building were the hydraulic-fill method, developed by the late James D. Schuler, rock-fill dams with imperious upstream face; and multiple-arch dams of various types. For reservoir control and regulation, there have been developed many unique devices, among which are bear-trap dams of several types, siphon and circular tunnel spillways, and rolling gates.

Truly, neither "the hand of man" nor his brain have been idle since the day of the Quaker Bridge Dam in 1885, and FitzGerald's own mind played no small part in the acceleration of this rate of progress.

In 1886, FitzGerald delivered a paper on "Evaporation" before the American Society of Civil Engineers. This has become classical and marked a considerable advance in the application of analytical methods to natural phenomena. In 1892, the late F. P. Stearns, Past-President of this Association, prepared a paper on "The Selection of Sources of Water Supply," which was about the first attempt in this country to formulate a method by means of which it was possible to compute the yield of watersheds, using as a basis data which had previously been observed. This study was followed in 1894 by a very valuable discussion on this matter prepared by C. C. Vermeule of the New Jersey Geological Survey. The analysis of run-off data by means of the mass diagram, probably first developed by Rippl in 1882, was greatly elaborated and introduced into this country by John R. Freeman in the report on Additional Water Supply for New York City in 1900.

Perhaps the most outstanding hydrological event in water-works history throughout the country in the past fifty years was the drought experienced during 1930. New England was fortunate in not being subjected to the extremes of this condition experienced elsewhere. While the annual precipitation in this section was considerably below normal, yet many of the limits reached in other years were not attained at this time. For instance, the low Boston rainfall for the years of record was that of 1910 with 28.33 in. or nearly 7 in. lower than that of 1930, and Springfield with several records lower than that of 1930. On the other hand, minimum records for precipitation for 1930 were established in many New England and neighboring localities. For instance, New Haven with 34.72 in., or 10.81 in. below normal; New Bedford with 28.04 in., or 18.14 in. below normal.

Ground water reserve was drained to a very low level, and the demands for replenishment permitted reservoir storage to fill more slowly than the rainfall seemed to warrant. While the flow of streams was very low, the minimum flows of record were not reached in New England and Eastern New York for the year as a whole, nor for the dryest month on many of the water-supply gathering grounds. As regards the Metropolitan (Boston) sources, the year 1930 produced the lowest mean annual run-off for the thirty-three years of record on the Wachusett watershed, 0.876 c.f.s. per sq. mile as against a previous low of 1.055 c.f.s. per sq. mile in 1911. The 1930 record was 34 per cent. of the rainfall for the year and 52.5 per cent. of the average run-off of the years of record. On the Sudbury watershed of the same system, the mean annual run-off for 1930 was 0.617 c.f.s. per sq. mile as against a previous low (1911) of 0.796 cu. ft. sec. miie. The 1930 run-off of this watershed was 24.4 per cent. of the rainfall for that year and 41.2 per cent. of the average run-off for the years of record. On the Croton (N.Y.) watershed, the mean annual run-off for 1930 was 1.021 c.f.s. per sq. mile as against a previous low of 0.857 c.f.s. per sq. mile in 1880. The 1930 run-off for this watershed was 35.1 per cent. of the rainfall for the years of record.

However, whether or not the annual precipitation and run-off were or were not the actual lows of the years of record, the seriousness of the drought produced by low rainfall is dependent to a great degree upon its uniformity or lack of uniformity during the entire period. From consideration of the conditions during the year 1930, it seems desirable in the interest of safety and continuity of water service that estimates of so-called "safe yield," based upon records of prior years, be considerably revised.

Beside storage to meet variations in yield during a year or a period of years of low rainfall, there is the development of storage facilities to meet fluctuations of shorter periods, and tanks and towers as well as small reservoirs on high land have been used to much advantage. In the earlier years, the steel tank set upon the hill tops and standing out against the sky line was evidence of utility regardless of any other consideration. More recently, architectural and landscape effects have been combined with these structures to the great improvement of surrounding property. Flat bottomed ground-level storage tanks date almost from the advent of iron and steel plates. The next development was the design of storage tanks so that the capacity was obtained by heights of the tank with relatively small diameter.

About 1892, several engineers conceived the idea of elevated storage tanks, the first installation being in Laredo, Tex., in 1892. These tanks had hemi-spherical bottoms, and the diameter of the tanks was determined by structural limitations. In 1907, the ellipsoidal-bottom tank was developed and first used for railroad supplies. This tank was a great improvement over former designs as it gave a greater diameter and less depth than the hemi-spherical shape and so reduced the variation in head against which the pumps must work. For use with tanks of large diameter and low ranges of head, a type of bottom has been developed which is claimed to be more economical than the suspended design. This type of bottom is partially suspended and partially supported by interior columns, and the form of the bottom itself is much flatter than in the other types of design, being somewhat similar to the "battledeck" steel floors.

Continued improvement in details of design has evolved an elevated reservoir far superior in appearance and in utility to the former "stand-pipe." Elevated tanks of capacity up to 2 000 000 gallons are being designed and installed. It is stated that one of the largest steel-tank builders in the country has installed twenty-three elevated tanks of 1 000 000-gal. capacity or more since 1925.

An outstanding advancement in the construction of elevated tanks during recent years has been the development of designs for tanks of large capacity and relatively low ranges of head as compared with the ranges in earlier tanks. This type of tank also lends itself to lowering of construction costs for storing a given quantity of water, tanks of from 25 to 35 ft. being the most economical design.

The tendency at the present time is toward tanks of all-welded or a

combination of welded and riveted design. Although there are still some major difficulties attendant on this process for tank construction, it is probable that methods and procedures will be developed that will eliminate altogether, or at least relieve the present objections to this method of construction, and that welded standpipes will soon be in general use.

Water Filtration.

Two methods of filtration are in general use today for water-supply purposes. These, in accord with the comparative rates at which water is passed through the filters, are designated "slow" and "rapid" sand filtration.

The first filter for a public water supply is said to have been constructed by James Simpson, Engineer for the Chelsea Water Company, London, England, in 1829. According to the New York Department of Health, this was probably the most valuable single measure ever developed for the protection of health and has been the chief factor in the great reduction in typhoid in the United States.

The first filter was built for service as a strainer to decrease turbidity, and, unknown to its designers, was performing a different and more valuable service than was expected, for the germ theory of disease was then unknown. Following a serious cholera epidemic in 1849, filtration of the whole water supply of the city of London was made compulsory by Act of Parliament in 1852. This marked the first attempt to purify water as a safeguard to public health.

Prior to 1880, few American cities had filtered water supplies, and storage and sunlight were the only agents of purification employed. The early microscopic work of Rafter, FitzGerald and Tookes in identifying the cause of disagreeable tastes and odors in water was the first step to modern methods for providing an attractive and palatable water supply.

While the Louisville studies by George W. Fuller, under direction of Charles Hermany, the engineer of the water works of that city, were epoch-making in advancing the art of mechanical filtration, the work of Edmond Weston at Providence, R. I., should be given credit as the first real study of this matter from a scientific point of view.

According to a statement of Harrison P. Eddy, the first water-works plant in the United States was built in Boston Mass., in 1652. It is stated by George S. Davison, that pumping machinery was used for the first time in 1754, the pump being made mostly of *lignum vitæ* and the force main to the reservoir of hemlock logs. This pump is said to have remained in use until 1862 and to have then been replaced by one of iron.

The first filter for water-supply purposes in America was built in 1871, but as late as 1900, only about 170 cities in the United States were supplied with filtered water. According to the same authority there were 16 water works plants in the United States in 1800, 83 in 1850, 422 in 1875, 600 in 1880, 3 500 in 1900 and 10 000 in 1926.

In 1869, what is said to have been the "first State Board of Health established by any American State; at least with objects as extensive as those now given to our charge," was authorized by the Massachusetts legislature. From that time down to within a decade, when a streak of so-called economy prevailed and found outlet in lopping off expenditures for work which politicians could not understand, the work and reports of the Massachusetts State Board of Health gave to the world more valuable information on measures affecting public health and well-being than any other similar body then in existence in the world, and provided a foundation for most of the sanitary work that has since been accomplished. All honor is due to Drs. Henry I. Bowditch, George Derby and Henry P. Walcott, Professors William Ripley Nichols and William T. Sedwick, Engineers Hiram Mills, F. P. Stearns and X. H. Goodnough, who often in the face of strong political hampering kept the faith entrusted to them by that act of the Massachusetts legislature in 1869.

Within the last thirty years or thereabouts water purification has become amenable to scientific control, although the art of filtration, along lines similar to those in use today, had been practiced for nearly a hundred years in England and on the Continent.

Following closely upon the first requisite of a water supply work, namely, sufficient quantity adequately controlled, came the matter of quality. As of today, matters of provision for safe and attractive water seem somewhat to overshadow the basic requirement.

On account of its limitations in handling waters with certain characteristics, the slow sand filter can be used to advantage only in exceptional cases. This type of filter is inefficient where the water is turbid or the color high. On the other hand, chemicals for coagulation or sterilization of effluent are not needed if conditions are right, less expert supervision is required, and the bacterial efficiency is generally higher than with rapid sand plants. The rates of filtration are so different with these two processes as to affect the area required for their construction. The modern slow sand filter delivers at rates from 3 to 8 m.g.d. per acre, the rapid sand filter having a delivery of from 100 to 150 m.g.d., for the same area. For these reasons, the rapid sand filter is more in evidence today than formerly; with improved methods of handling and more convenient design for operation, it has practically gained the field, and it is probable that few slow sand plants will be installed hereafter. On the other hand the advantages of the slow sand process are so outstanding that, where conditions are suitable for this type of filter, its use will probably never be entirely discontinued. Its capacity for delivery may be considerably increased by pre-filtration.

The first works in this country for the filtration of public water supplies were built under the direction of the late James P. Kirkwood, in the early 70's for the municipalities of Poughkeepsie and Hudson, N. Y. These filters were of the slow sand or "English" type, so-called from

filters of similar characteristics which had been in use in England for many years.

The filtration of water as a general adjunct to water-supply works in this country began to be considered about the middle nineties, although the Massachusetts State Board of Health had taken steps to establish an experimental station at Lawrence about 1887 and in 1891–1892 this organization had under investigation the ability of ordinary sand filters to remove typhoid fever germs from water used for domestic purposes. It is stated,[9] that in 1880 about 30 000 people were supplied with filtered water; in 1890, 310 000; in 1900, 1 860 000; and in 1917, 18 263 000. The increase after 1900 is probably due to knowledge of the terrific outbreak of Asiatic cholera in Hamburg, Germany, and the severe epidemics of typhoid fever which visited many American cities about this time.

The first modern slow sand filter in the United States was installed at Albany, N. Y., in 1897 from the designs and under the supervision of the late Allen Hazen, Past President of this Association, for the purpose of purifying water from the Hudson River. This plant with various modifications has been in use up to the present time, and is now about to be superseded by a gravity supply from upland sources.

Rapid filters came definitely into well-being about 1897 due to the Louisville experiments of George W. Fuller, followed by the construction of the plant of the East Jersey Water Company at Little Falls, N. J. in 1902. All plants of this character built since have been designed in about the same manner, and whatever improvements have been made are of detail rather than of principle. Probably one of the greatest advances in rapid sand filtration operation is due to knowledge of hydrogen-ion control and the modern processes of conditioning water by chemical applications, and, more recently yet, the pioneering use of activated carbon.

The United States Treasury Standard of quality of drinking water on interstate carriers has set a criterion which is now of almost universal application in this country.

In spite of the swing of the pendulum in water purification toward rapid sand filtration and its concomitant use of chemicals and the well-known urge for speed and cheapness in construction and operation which is almost a fetish in this country, and while the desire of the consumer may be stifled, it can never be asserted with truth that people like "doped" or "reclaimed" water.

Water must be had in order to support life and any water is better than none, provided it is safe and clean, but as has truly been said "water consumers have an absolute right, emergency cases being excepted, to demand a tasteless as well as a safe drinking water supply." It might well have been added that a water which as a result of treatment comes as near as possible to that which Nature provides is the most desirable water for human consumption.

The latest development in providing water of such a character are the pre-filter plants recently installed to work in connection with the older slow sand filters of the Water Supply of the Metropolitan District of London, England. Here is a water taken from the River Thames, a stream flowing through one of the most thickly populated districts of the world, which after being subjected to the double filtration process is delivered to consumers in such condition that even disinfection after filtration is not absolutely necessary. How many of the purveyors of "doped" rapid sand water in this country can supply such a water as this in large quantities?

Disinfection.

Disinfection by chlorination came into general application as a water supply safeguard through its use in 1904–1905 at the Lincoln filters by Sir Alexander Houston, Director of Water Examinations of the London (England) Water Board, and one of the foremost sanitary engineers of the world. In the United States, George W. Fuller tried out hypochlorite of soda and chlorine at the Louisville Experimental Filters in 1896, but the first successful attempts at its use were made by George A. Johnson with the raw water of Bubbly Creek at the Chicago Stock Yards. Later, as a safeguard for a public water supply, it was used at Jersey City, N. J.

The form in which chlorine was used in the first efforts at sterilizing was bleaching powder in solution. In 1910, Major C. R. Darnall of the United States Army demonstrated that liquid chlorine could be successfully used in water-supply work. This form of the chemical has now come into almost universal use because of the ease of its application by the apparatus developed chiefly through the mechanical ingenuity of Messrs. Wallace & Tiernan. Quoting Sir Alexander Houston: "Chlorine has come to stay . . . there has been a gradual change of front from hostility to tolerance and from tolerance to appreciation."

Although one of the first to recognize and use chlorine as a sterilizing agent to safeguard public water supplies, in his latest report, Sir Alexander[10] says that: "With all the power at his command" he "urges the importance of not regarding chlorination, however carefully and successfully practiced, as the ultimate solution of all water problems. We must still seek virgin sources of water supply and still retain and maintain, as far as this is reasonably practicable, the old established armory of defence. Chlorination should be regarded primarily as a means of amplifying a security which has, humanly speaking, already been secured."

As the quality of water improved from a sanitary standpoint, the matter of more attractive and palatable water was also demanded, and George C. Whipple, starting his work at Chestnut Hill Reservoir, and carrying his investigations over a long term of years, definitely determined

the causes to be in the growth and decay of certain microörganisms. To get rid of this trouble, Moore and Kellerman of the United States Department of Agriculture developed a method of control by use of copper sulphate, which is in use at the present time.

In another part of the report referred to above it is stated: "Deep reservoirs, with sides which do not slope too much, clean bottoms, good circulation and the use presumably of as pure a water as possible for abstraction purposes are factors which seem to keep excessive growth of algæ in check." Was F. P. Stearns ahead of his time in his advocacy of cleaning up water-supply reservoirs, and is the tendency now toward abandonment of the cheaper methods of procedure?

Up to recent years, many waters of excellent quality otherwise, have not been generally used on account of the large quantities of mineral or other matter which rendered the water too hard or corrosive for general use. Today, the matter of water softening, practiced abroad for nearly a century, is being well and economically handled in this country by modern plants designed particularly for this purpose. The so-called "excess lime method" of softening, purifying and sterilizing water is receiving much attention, with water overdosed with lime to bring about not only a softer water for use, but one which is safe as regards water-borne epidemic disease.[11]

Among the later improvements of water supplies should be mentioned iron removal plants, whereby many ground-water supplies, containing objectionable quantities of iron and manganese, are made usable. For elimination of tastes and odors "pre-ammoniation" and activated carbon have been used with marked success.

On account of growth in population and increase in objectionable wastes from industry, the matter of stream purification is now receiving close attention all over the country, and the best thought of today is insistence on purification of sewage effluents before discharge into rivers and other bodies of water, in order to lighten the burden on water-works plants drawing water from these sources.

Experience during the drought of 1930, however, indicates that while a "processed" water may be safe from a bacteriological standpoint, it may not be a desirable water for human consumption.

Gate Valves.

In the design of gate valves, so important in a water-works system, the tendency, as in other appliances, has been toward a heavier and more durable product. Bronze stems are now in general use. The material of which these stems are made has a tensile strength of at least 55 000 lb. per sq. in. in place of 30 000 to 35 000 formerly considered sufficient. Bodies are now being made of service steel or of cast iron with a tensile strength 50 per cent. greater than that of twenty years ago.

In the matter of service, motor operation is supplanting hand operation on the larger sizes of valves, and cylinder-operated valves are coming into general use.

Meters.

Up to about forty years ago, water was almost universally sold by what was known as the "flat" or "fixture" rate, and payment bore little or no relation to quantity of water used. The need of payment in proportion to use being recognized, some means for ascertaining the amount was necessary, and the water meter in its early form came into being.

The first water measuring device is credited to Samuel Crossley, in England, about 1825. It is a long step from Crossley's meter to that of the present day with its mechanism made and put together with almost watchlike perfection of detail and accuracy of registration. This advance is one of the marvels of water-works progress. Twenty-five years ago, in a group of 100 large cities, only about a quarter of the services were metered. Today, in the same group, at least 80 per cent. of the services are metered. The Boston Metropolitan District is an excellent example of this progress; its results have been previously mentioned in this paper. In 1900 about eight per cent. of the total number of services in this district were metered; in 1930, including all additions subsequent to 1900, about 99 per cent. of the services were metered.

In view of the results obtained by metering of services, both as to increase in income and payment for value received, it is a serious criticism on public methods of carrying on municipal affairs that will permit the retention of "flat" rates in many of the largest cities of the country: New York, Chicago, Philadelphia, St. Louis, Baltimore, Buffalo, Denver and Pittsburgh among others. That this condition is due to influence entirely remote from water-department desire and urge in every case is a matter of record, and, so far as allowed by political control, services are being metered in municipalities as fast as possible. While accurate figures are impossible of ascertainment, it seems a fair estimate to state that at least 70 per cent. of all services attached to public water supply systems of the country are metered.

The first water meter patent was granted in this country in 1837 for a diaphragm meter similar to a gas meter. For various reasons, this type of meter was not successful as a measurer of water. About thirteen years later, a patent was granted for a rotary meter, and in 1851 two patents were granted to Capt. John Ericson of "Monitor" fame, one for a rotary meter and one for a piston meter.

Excepting meters of the Venturi and orifice type, broadly speaking, there are but two types of water meters in general use today — those operating on the positive displacement principle, and those working on the inferential principle. Positive displacement meters are those which successively fill a chamber and displace water therefrom with direct count

of the filling of the chamber translated into quantity. Inferential meters depend upon the rotation of a wheel or helix operated by the flow of water, the quantity passing being inferred from the rotation of the interior device actuated by the velocity of the current.

In 1858–1868, reciprocating piston-type meters came into use and still continue to be employed, although principally confined to oil and hot water. This meter was very reliable but high in first cost and in repairs and, in the larger sizes, heavy and cumbersome. In the early eighties a successful rotary meter was brought out and attained considerable use, being accurate and durable. The objection was its high cost of manufacture and retardation of flow. With the increasing demand for a lower-priced house meter came the development of the velocity and disk meters. These hold the front today in America, while in England and on the Continent, the displacement meter is still in general use. The first successful disk meter was brought out by John Thomson in the early eighties. It is said that probably 90 per cent. of the meters in use in this country today are of the disk type operating on the same general principle as the Thomson meter, the only change being in minor improvements for accuracy of registration and lessening of retardation of flow.

For meters above 2 in. in size, it is now considered best practice to use the velocity meter instead of the disk meter, as the former has nearly double the capacity at the same rate of flow but is not so accurate on low flows as the positive displacement meter. Urged on by the necessity for developing a measuring device that would be accurate on low flows and permit high flows with minimum loss of head, a so-called compound meter was put on the market about 1910. This, as the name implies, combined a disk meter for recording accurately with low flows with another meter of the velocity type for high flows with an automatic valve, which, according to demand, shunted the water through either the low or the high duty meter, the amount in each case being registered on a dial attached to the separate meters. As in other water-works appliances, the tendency has been to lower the cost of meters, and increase their capacity and reliability of record, until today the meters put on the market by any of the eight or ten reliable meter companies are marvels in all respects as compared with those of fifty years ago.

In 1916, after considerable discussion, the report of its Meter Rate Committee was adopted by this Association. This report was a modified form of the Coffin report on the same matter made a decade earlier. In 1923, the provisions of this report were also adopted by the American Water Works Association, and the sliding scale then proposed is now in general use with gas and electric companies.

Another outstanding advance in this branch of water industry was the acceptance by the meter manufacturers of the Standard Specifications for Cold Water Meters adopted by the New England and American Water Works Associations in 1921. This act curbed the tendency

of mechanical meter manufacturers to produce special features, which were both wasteful and annoying in water-department work, and tended to improve mechanism by urging manufacturers to sell on merit.

While about 80 per cent. of the water purveyors purchase and own the meters, some of the largest cities in the country still require the consumers to buy the meter and pay for repairs.

A further great advance in meter practice is the formation of the American Water Meter Institute, composed of manufacturers of water meters who now get together and try to eliminate methods and practices detrimental to the water-works industry.

An outstanding event in hydraulic engineering was the application of the principle of the Venturi tube to the practical measurement of large quantities of water by the late Clemens Herschel, Past President of this Association. Of almost equal value from a practical point of view, was the design of registering and recording appliances for use with this meter by the Builders Iron Foundry, working through F. N. Connet. The next important advance in the measurement of water came with the adoption of the principle of the Pitot tube for measuring flow in pipes by E. C. Cole. The Pitometer, perhaps, more than any other one invention, has helped water-supply distribution work in its adaptability to waste-prevention work and to ascertain, at comparatively small expense, the flow of water in pipes under pressure.

Water-Works Appliances.

Among the outstanding advances in water-works appliances are the machines for tapping water mains under pressure. As late as 1885, it was common practice to shut down the main when a connection was required, tap a hole in the pipe and *drive* in the tapered end of the corporation cock. In 1871, the Mueller Company placed on the market a water-tapping machine which, so far as is known to the writer, was the first of its kind in this country and immediately revolutionized practice in service-pipe installation.

Following this invention came the ground key and inverted key type of curb cock, the latter a distinct advance, as it permitted the plug of the cock to be loosened when operating from above.

Water-pressure regulation followed about 1880, and soon after, the lead flange joint for use in connecting brass service-pipe fittings to the main was adopted, thus early supplanting the lead goose neck connections hitherto used for this purpose. None of these appliances, which are now so universally used, that most members of the younger generation have no knowledge of former troubles, were immediately adopted, for "good enough for father, good enough for me" has a tight hold in many water departments even today.

Little improvement has been made in service boxes since the advent of the sliding top about 35 years ago.

So far as is known to the writer, the first water-meter testing machine was the invention of Robert Gow, then superintendent of water works in Medford, Mass., a man of sound water-works sense and an enthusiastic member of this Association. With the introduction of meters for measuring water, Gow recognized the necessity of some mechanical means for testing the flow through the meter in order to satisfy a skeptical water consumer. Being of an inventive and inquiring mind, he developed a machine, which, even today, has changed little in general makeup although it has been considerably perfected as regards details of operation.

For service-pipe connections between street mains and consumers' houses, lead pipe, which seems to have been the most generally accepted material from Roman times, was formerly used. Due, however, to the susceptibility of lead to attack by some waters and consequent chance of lead poisoning, the use of lead pipe gradually decreased, and, in its place, came generally the use of wrought iron, plain or galvanized, which gave excellent service. This was followed by steel tubing, which with some waters and grounds had comparatively short life. More recently, there have appeared copper tubing and red brass, both of which have advantages in resistance to corrosion, which causes both destruction of pipe and reduction in capacity. Copper tubing has the added advantage of flexibility, an important property in the avoiding of underground obstructions. It also seems to have other advantages over the more rigid pipes. What may be its defects, if any, can only become known after a considerable period of trial under workaday conditions. Under New England conditions, wrought-iron pipe lined on the inside with cement mortar has given satisfactory service for fifty years.

Fire Protection.

In 1892, John R. Freeman, Past President of this Association, presented a paper "Arrangement of Hydrants and Water Pipes for Fire Protection." This paper received much favorable comment and was the precursor of water-supply interest in fire-protection work. While the reduction in insurance rates is due to a number of factors, yet the public water supply — its quantity and its pressure,— at least, are major factors. Urged on by Freeman, the Mutual Fire Insurance Company began a drive for better fire protection. Later, the National Board of Fire Underwriters through its engineering department carried this good work into all of the large cities of the country.

Since 1916, all cities and towns which the National Board has inspected have been graded with reference to their fire defences and physical conditions. In the grading schedule used for this purpose, water supply is assigned 1 700 points out of a total of 5 000; *i.e.*, nearly one-third of total fire protection is due to the water supply and its appurtenances. The number of cities now graded by the National Board is nearly 400, and

includes practically all cities of over 25 000 population as well as some smaller ones. In 72 cities in 27 states, varying in population from 22 000 to over 3 000 000, graded in the past two years, and on which there were previous gradings ten years back, 58 showed improvement, the average being third class in 1920 and second class in 1930, an average improvement of about 33 per cent. For the 72 cities mentioned, the average improvement was about 24 per cent. In an indirect way this improvement indicates the advance in water-supply conditions during the past decade and the money which this improvement has passed back to the consumer's pocket.

The outstanding result of these endeavors is found in the reduction in the average rate of premium charged per $100 insurance as follows. This reduction reflects the increase in fire protection work, which lessens risk and so saves to the community payments for insurance as well as securing greater continuity of employment by protection of industry.

1900 – $1.0036	1920 – $ .9617
1910 – $1.0822	1930 – $ .7691

From these data, it appears that the average rate of insurance throughout the country has decreased 31.31 cents per $100 value, and is now about 71.2 per cent. of what it was twenty years ago. This result, however, has been obtained at appreciable expense to water departments in cost of excess distribution work.

As reflected in special risks, the following insurance rates are applicable to a brick dwelling, within 500 ft. of a highway, in an eastern locality. These are one-year rates with three-year coverage at two and a half times greater, with the same percentage of reduction applying to frame dwellings:

1900 – 25¢ per $100	1920 – 12¢ per $100
1910 – 25¢ per $100	1930 – 10¢ per $100

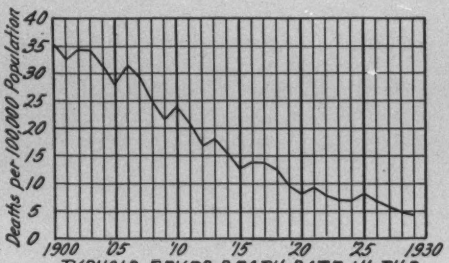
For similar coverage in country districts, with no water supply, the rate is 45¢ per $100 for one year. For factory and storehouse risks the spread is even greater between those that have public water-supply service and those that do not.

It is worthy of note that, in the past twenty years, insurance coverage has been reduced 60 per cent.; that is, for the same amount in premium, a property owner can obtain two and a half times more coverage than he could twenty years ago. This is particularly interesting in view of the fact that building costs have about doubled in this period. What the cost of these reductions has been to water departments has been worked out by the National Board of Fire Underwriters. As referred to population served, the cost of that portion of a water supply system which is devoted to fire protection varies from about 56 per cent. of the total cost for a community of 10 000 people to about four per cent. of the total

cost for a community of 300 000. In spite of this record, water departments have received very little return on the cost of this service to them.

Public Health.

Water supply and public health are so intimately related, that a marked trend in one is certain to be reflected by a similar tendency in the other. On this account, it seems in accord with facts to state that the most outstanding evidence of progress in water-supply work is found



TYPHOID FEVER DEATH RATE IN THE UNITED STATES REGISTRATION AREA.
(From the U. S. Census Bureau Reports, 1900 to 1929, incl.)

Fig. 8.

in the improvement of the public health generally, particularly in the decrease in water-borne typhoid fever, as shown by public health statistics. This condition is excellently illustrated by the curve in Figure 8.*

In 78 of the largest cities of the country, in the period 1910–1930, the typhoid death rate per 100 000 dropped from 20.54 to 1.6.[12] In the fifty-year period (1880–1930), the death rate from typhoid fever has dropped from 50 to 4.9 per 100 000 population in this country.

In "Preventive Medicine and Water Supply," Sir George Newman, commenting on improvements accompanying the introduction of a good water supply, instances the lessening number of deaths from cholera, epidemic diarrhea and dysentery, as well as typhoid, and states that deaths from typhoid have declined from 370 per million in 1875 to 12 per million in 1924. He states also that the effective supervision of water supplies that has accomplished this result "includes control of the sources, gathering grounds and catchment areas, of methods of filtration and storage . . ." and concludes, "Happily there is now widespread recognition of this primary public health requirement, a wholesome and sufficient water supply."[13]

*Reproduced by courtesy of Abel Wolman, Chief Engineer, Maryland State Board of Health, and appearing in his paper, "Water Borne Typhoid Fever Still a Menace," *Am. Jour. Pub. Health*, October, 1930.

Financing and Management.

The advance in methods of management and control of water-supply systems during the half century is noteworthy. They have passed through the stages from exploitation by private interests where the consumers often had little or no consideration, to governmental control by state regulatory commissions, charged not only with the duty of compelling safe water supplies, but also of seeing that the charges therefor shall be proper to both consumer and purveyor. That this has been of immense advantage to consumers and utilities alike goes almost without saying.

Among the first, if not the first, to undertake services of this kind was the Wisconsin Railroad Commission charged with oversight of public-utility service. The result of the work of these commissions has been to put water utilities, both publicly and privately operated, on a sounder financial basis and to bring about rates for services which are more equitable, both to operator and consumer.

Metropolitan Districts.

With the increasing demands for water, sewage disposal and other municipal necessities there has developed the plan of pooling resources and, by coöperation among neighboring communities, getting for all that which would have been difficult for some and impossible for others. The London (England) Metropolitan District is, perhaps, the best known of this type, but many others, similarly formed, are now functioning in this country. The plan has come into more general use within the past forty years. An outstanding effect of a late effort in this line is the Metropolitan Water District of Southern California, including Los Angeles and surrounding cities.

It is a long stride from the water supply works of the city of Boston in 1885, with a demand of 27 m.g.d and the Sudbury Aqueduct, 15.9 miles long, 9 ft. wide and 7.67 ft. high with a delivery capacity of 100 m.g.d. to the Metropolitan Aqueduct of Los Angeles with its 266-mile length, its 16.9-ft. height and 19.7-ft. width and 850-m.g.d. delivery. Yet the Boston water supply of 1885 was one of the biggest in the country at that time.

Price Trends.

There have been widespread changes in prices of both materials and labor during the past fifty years. Cast-iron pipe, as previously stated, decreased from $35.68 per ton in 1882 to $15.48 in 1897–1898, and gradually rose to a peak of $75 per ton in 1920, whence it has since dropped to $36 per ton in 1931.

Common labor could be hired in 1880 to 1889 at 13¢ per hour with a 10-hour working day. From 1890 to 1903, with a working day decreased to nine hours, the hourly rate was from 14 to 16¢. In 1907, with the advent

of the eight-hour day, the hourly rates advanced to 22¢, in 1915 to 35¢, in 1920 to 68¾¢, in 1925 to 60¼¢, where it now stands.

Paralleling changes in labor rates has come machine work. This has been particularly evident in pipe-laying work within the past decade. Efficient machines are now on the market for excavating, backfilling, rock work and similar services thus reducing construction costs.

According to the report of the City Engineer of Providence, R. I., for the year 1893, the cost of installing cast-iron pipe, including all labor and material, except hydrants, was:

6-in. pipe	$0.725 per ft., excluding cost of pipe,[14]	about	$0.25
8-in. pipe	0.973 per ft., excluding cost of pipe,	about	0.27
10-in. pipe	1.244 per ft., excluding cost of pipe,	about	0.30
12-in. pipe	1.593 per ft., excluding cost of pipe,	about	0.37
16-in. pipe	2.403 per ft., excluding cost of pipe,	about	0.52

In eight bids received for installing cast-iron pipe at Warwick, R. I., the lowest bid was: 6-in. pipe $0.43, 8-in. pipe $0.46, 10-in. pipe $0.48, 12-in. pipe $0.50, 16-in. pipe $0.89 per ft.

In 1931, bids received for installing cast-iron pipe at Canajoharie, N. Y.,[15] as given in *Engineering News-Record* were as follows:

8-in. pipe	42¢ per ft.
10-in pipe	42¢ per ft.
12-in. pipe	44 to 58¢ per ft.

The accompanying table, arranged from data furnished by the United States Cast Iron Pipe & Foundry Company, gives the average and range of prices for cast iron pipes, from 1850 to 1930. From 1850 to 1875 inclusive, cast-iron pipe prices ranged from $32.15 per ton to $58.05 per ton, with an average of about $46 per ton. In the quarter century, 1873 to 1898, there was a gradual drop from the earlier high of $58.05 to $15.48 per ton with gradual recovery to 1916. In 1917, there was a sharp rise in prices to $49.68 per ton, increasing to a high of $68.92 in 1920, with a maximum of $74 per ton in that same year. After that peak, there was a gradual decrease to $38 per ton in 1930.

The advent of centrifugally cast pipe has revolutionized prices as well as product. Recent quotations of centrifugally-cast pipe are as follows:

Diameter. Inches.	Price per linear foot. Class 150.	Equivalent Price per ton. Class "C".
6	$0.46	$25.00
8	$0.65	$25.00
12	$1.14	$25.00
16	$2.00	$28.00

These prices are about the same as those for which pipe was purchased in 1885. In addition, there are further economies due to the fact that pipes made by the centrifugal process are now being cast in 16- and 20-ft.

AVERAGE YEARLY PRICES ON CAST-IRON PIPE, 1850–1930.

Includes all classes Bell and Spigot Pipe. Prices F.O.B. Delaware River Foundries 1850–1901; 1902–1930. F.O.B. Birmingham District.

Year.	PRICES PER TON. (2 000 Lbs.)	Year.	PRICES PER TON. (2 000 Lbs.)		
	Average.		Average.	Max. Mo.	Min. Mo.
1850	35.72	1900	22.33	..	..
1855	40.18	1901	21.63	..	..
1860	32.15	1902	25.83	30.00	21.50
1865	58.05	1903	25.85	29.00	22.75
1870	50.01	1904	20.13	22.50	19.00
1871	53.58	1905	22.79	24.00	22.00
1872	51.79	1906	25.46	30.50	24.00
1873	58.05	1907	30.75	31.50	28.00
1874	43.76	1908	21.08	26.00	20.00
1875	37.51	1909	20.46	21.50	19.50
1876	31.26	1910	20.92	21.50	20.00
1877	25.00	1911	18.92	19.00	18.50
1878	23.22	1912	21.96	23.00	19.00
1879	29.47	1913	21.00	23.00	19.00
1880	29.47	1914	18.58	19.00	18.00
1881	33.04	1915	18.89	21.85	17.85
1882	35.68	1916	26.16	34.35	23.35
1883	32.15	1917	49.68	60.35	36.35
1884	26.79	1918	53.85	60.00	49.15
1885	25.00	1919	51.17	60.00	45.00
1886	26.79	1920	68.92	74.00	60.00
1887	28.58	1921	44.50	55.00	32.00
1888	25.00	1922	37.33	43.50	33.00
1889	23.04	1923	49.17	52.00	43.00
1890	24.65	1924	45.88	48.00	40.00
1891	23.04	1925	41.67	42.00	40.00
1892	21.43	1926	40.67	42.00	38.00
1893	21.30	1927	32.88	38.00	27.50
1894	18.47	1928	32.46	38.00	27.00
1895	17.95	1929	38.00	38.00	38.00
1896	17.64	1930	38.00	38.00	38.00
1897	15.48	1931			
1898	15.48	1932			
1899	21.17	1933			

lengths, a saving of one joint in every 48 ft., in the case of the former, and two joints in every 60 ft., with the longer lengths.

The economies due to savings in material and methods during the past fifty years have offset to considerable extent the increases in freight rates and labor costs during the same period. Among them are:

1. Better and lighter pipes for the same service.
2. Cheaper joint-filling material and less number of joints to fill.
3. Less labor in laying pipe.
4. Machine excavation and backfill.
5. Cheaper and better methods of rock excavation and pavement cutting and replacement.

Engineering News average annual construction costs index numbers[16] as related to 1913 are as follows:

1903	$ 93.90	1910	$ 96.33	1917	$181.24	1924	$215.36
1904	87.40	1911	93.43	1918	189.20	1925	206.68
1905	90.55	1912	90.70	1919	198.42	1926	208.03
1906	95.10	1913	100.00	1920	251.28	1927	206.24
1907	100.55	1914	88.56	1921	201.81	1928	206.78
1908	97.20	1915	92.58	1922	174.45	1929	207.02
1909	90.92	1916	129.58	1923	214.07	1930	202.85

LITERATURE.

The articles appearing in the JOURNAL of this Association are a record of the advance in water-works practice in the past fifty years.

Thomas Box issued his edition of "Practical Hydraulics" in England in 1870, and in the United States some fifteen years later. W. R. Billings, Superintendent of Water Works at Taunton, Mass., a member of this Association, prepared a series of articles on the Details of Constructing a Water Works Plant, which were ultimately combined in book form and printed by *The Engineering and Building Record* in 1889. The first general treatise appearing in this country, on the subject of water-supply engineering, was entitled a "Treatise on Water Works," by Charles S. Storrow. Following this was a compilation by Col. J. T. Fanning, "A Treatise on Hydraulics and Water Supply Engineering," first published in 1877 and even now a standard reference book, having passed through many editions. Today, the treatises on water supply and similar matters are almost numberless, but it can almost be said that in this field, as well as that of general literature, quality and quantity have hardly kept pace in the half century now gone by, particularly in American and English works on hydraulics.

Among the outstanding books for practical water-supply work may be mentioned "Public Water Supplies" by Turneaure and Russell (1901); "Water Works" handbook by Flinn, Weston and Bogert (1916); "Manual of Water Works Practice" (1925) by the American Water Works Associa-

tion; and the "American Civil Engineers handbook by Merriman and Wiggin (1930); also "Water Supply" by Folwell and "Water Supply Engineering" by Babbitt and Doland.

In the preparation of this paper, the author has received help in overflowing measure from many friends, and he feels under great obligation to all who have lavishly furnished him with data. While an attempt has been made to thank each of them individually, it seems impracticable to mention them by name in this paper, and opportunity is now taken to thank them collectively for the trouble taken and the courtesy shown.

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[14] Cast-iron pipe at this time was quoted at $21.30 per ton, f.o.b. foundry. Assuming "C" pipe and other materials to make a total of $27 per ton.
[15] July 30, 1931.
[16] Engineering News Construction Costs — 1930.

LOOKING BACKWARD.

A SYMPOSIUM.

[December 9, 1931.]

REMARKS BY MR. A. W. F. BROWN.*

While I do not think that I can add much to this meeting, I shall, as requested, look back for just a moment on my town of Fitchburg, Mass., and tell how things stood about 1887, in contrast to the present.

In those days 4-in. pipes supplied our hydrants. The material was cement-lined wrought iron which is now mostly superseded. In its place we have larger sized cast-iron pipe. While most of us do not like cement lined pipe for large conduits we have one section 1 400 ft. long, carrying water from the reservoir into town under a maximum pressure of 60 lb. per sq. in., that has not had a leak or troubled us in any way for forty years. There are no taps on it; it is just a supply main; but our experience speaks pretty well for the old pipe.

Another thing: Our reservoirs were protected at that time by about 100 acres of municipally-owned land. This land was woodland, just cord-wood stuff. We did not care anything about it. We knew it was there and sometimes went hunting in it. Now we own about 1 800 acres, and the question of forestation is quite an important consideration. The land has to be looked after; it has to be planted. There are old farms on it that should be cleared up and put into trees. All of this is a new problem.

On services, we used in those days, galvanized iron, black tar, cement-lined, and lead pipe. The old fashioned tarred pipe, was quite a pipe. I dug up a piece last year that had been in service for forty years. It was coated with gas tar, and that pipe was just as good, inside, forty years afterwards as it was the day it was laid.

Our meters were generally made of iron. They rusted quickly; but we got fair registration, and in some ways they were satisfactory. Today, with copper service pipe, modern meters, big mains, and reforestation conditions, we are getting along quite differently.

REMARKS BY MR. JOHN C. CHASE.†

It is a great pleasure to come here today as a guest of honor, and I fully appreciate the invitation, although I am a pretty regular attendant without special invitation.

Perhaps any prestige that I have is that I am with one exception the senior member of the Association. I might also say the senior in age, and the first member to be elected outside of New England.

*Registrar and Superintendent of Water Works, Fitchburg, Mass.
†Derry, N. H.

The program announced "Looking Back," so I should perhaps look back to 1883 when I was living in North Carolina and saw in a water-works publication that there was to be a meeting of water-works superintendents at Pawtucket, R. I. As I was coming North at that time I ventured to stop off, on the chance of being allowed to sit in with them. I was welcomed with open arms and made the acquaintance of the pioneers, Messrs. Ellis, Hall, Holden, Coggeshall, Darling and others whose names do not now come to me.

I was so pleased with my reception that I ventured later to ask Secretary Coggeshall if I could be admitted to membership. He said there was nothing in the by-laws to prevent, so my application went in at the next meeting, in the spring of 1884, at Lowell, and I was duly elected. One of the Executive Committee, which did the electing, came to me afterwards and said, "You will probably hear something about that election and I want to set myself right with you. I opposed your election, not for any personal reason, but I felt that we should keep this a New England affair, and that you, in the southern states, should have an association of your own, that the middle states and the western states should have their associations, and that the American Association should be the parent of all." I assured him that I had no feeling whatsoever regarding the matter. He also said, "I think we are opening a door which we will sometime wish we had kept closed." I assured him that if later they felt that it was desirable to "close the door," I would willingly withdraw from membership, but the following year the door was thrown wide open, and, as you well know, no pent-up New England has restricted our activities; we have had meetings and officers outside of New England, the Association has prestige from the Atlantic to the Pacific, and I am proud to be one of your number.

Looking back a little further. My first connection with water-works engineering was something over sixty years ago, on some preliminary surveys in an engineer's office, but it was in the early seventies that I became actively connected with construction. At that time, cement-lined wrought-iron pipe, was used extensively on account of the extremely high price of cast iron. It had great merit as a conductor of water, but certain structural defects were soon manifest, and in a few years it was abandoned as cast-iron pipe came down in price. I think the city of Manchester, New Hampshire, saved enough in the use of this pipe to substitute cast-iron pipe when it became necessary several years later. I do not think that they have any wrought-iron pipe in use there at the present time. Of course you are familiar with the later developments in the manufacture of cast-iron pipe, made by the centrifugal process and its interior coating of cement, making it an ideal conductor of water.

The next matter of note at that time was the beginning of the use of water meters. I installed in 1873 the first water meter in the city of Manchester. Then there were only two kinds in use, both of the piston

type, but about that time the age of development began, which has resulted in the rotaries and the disks of the present day.

As showing the growth of the meter business, with which you are probably as familiar as I am; in 1886 I bought and installed in a North Carolina city twelve of the first one hundred meters of a new type, the first product of one of the present large meter manufacturing concerns. I am informed that the product of that one concern has now exceeded a million and a half, so that you can readily see what the growth has been since 1886 of that particular concern. It has been a revelation to me in attending the annual meetings of the Association to see the exhibits of water meters of the various types.

Another noteworthy occurrence of that period was the discovery that water needed something more than a chemical analysis to determine its fitness for household supply.

About that time William Ripley Nichols, Professor of Chemistry at the Institute of Technology, made the axiomatic statement that "while chemical analysis assisted in determining the quality of water, it only assisted," and at that time began the study of purification by sand filtration. Sedimentation and filtration had long been in use by western and southern cities, where the muddy supply could be purified in no other way. Mechanical filtration began in the early eighties and is now a well established method of purification.

Of course there has been a great change in the type of reservoirs, and pumping engines. The "Holly system" was making a strong bid for favor when we built the water works at Manchester. The direct pumping idea was practically a modification of the factory fire-protection of the time, but it was fought very bitterly by those who were interested in having showy works.

The city of Manchester had surveys made in 1871 for a water-works system. Nine different sources of supply were discussed, and the one that to my mind now was the one of all others to have been selected, although I did not realize it at the time, was a gravity supply several miles away, in a country that would yield water that would be practically uncontaminated. The ambitious engineer felt the urge to construct a system which would make more show than a water main running a dozen miles through the woods, so a very elaborate system with dam and canal pumping station, with mains and reservoir was constructed. The supply selected was a lake about four miles from the city, an admirable site for a fine park. People began to build about the lake, and in order to prevent contamination of the water they were forced to give up their holdings to the city, thus diverting from taxation a very valuable tract of land. I instance this as an illustration of what can be had by "vision."

Dr. Walcott told me a number of years ago that Boston had practically settled its water supply problem for a hundred years by going on from the Sudbury River, to Wachusett, and then on to what is being taken

at the present time. The source of supply is practically free from contamination, flowing by gravity and also developing power that is of considerable value.

Standpipes came into general use only a short time before this Association was founded, and to quite an extent have been succeeded by tanks on a tower where the water is up where it will all be available, instead of having one third, or possibly one half of it, in the bottom of a standpipe where it can only have a very restricted use or be drawn out to be wasted. A personal experience showed that the cost of a 50-foot tank on a 75-foot tower was no more than that of a standpipe of the same height and proportionate diameter, and the water was stored at an average height of 75 feet instead of an average of 62 feet with the lower portion unusable.

I could go on indefinitely telling about personal experiences, but I refrain. One prominent feature of our early monthly meetings was the "rum pudding," as our friend Walker characterized it, which was brought in on platters and placed where we could help ourselves. Later, as you probably remember, and even before Walker passed out, the pudding was less lavishly dispensed and later the rum flavor went into the discard.

It has been a great pleasure to come here, and I hope I have not bored you with my rambling reminiscences. There are very few left of those with whom I was associated in the early days of the Association; their places have been filled by the younger members, whom it is always a great pleasure to meet, but as I look around and see so many new faces I can't help thinking of the lines of Holmes:

> "Well, Time with his snuffers is prowling about
> And his shaky old fingers will soon snuff us out;
> There's a hint for us all in each pendulum tick,
> For we're low in the tallow and long in the wick."

REMARKS BY MR. BYRON I. COOK.*

I was a superintendent of water works from 1889 to 1901. At my first opportunity after becoming superintendent I joined this Association, and it is a wonder to me that there is anyone who is connected with water-works construction or management in New England or elsewhere who does not become a member. I early got acquainted, and the corner talks with the different members of the Association have always been of great value to me. I learned a lot of things.

I very early made a visit to Mr. Salisbury at Lawrence and he showed me the method of making services by the tinker's way. The tinker's way is still in use in my city and has never given me any trouble. That is cupping the joints.

In 1901 I resigned as superintendent and entered the Inspection

*Inspector, Insurance Department, Factory Mutual Fire Insurance Company, Woonsocket, R.I.

Department of the Factory Mutual Fire Insurance Company. In other words, I am one of those fellows that comes around and sizes you up once in a while. My association with the insurance company has been very pleasant, and I have always had very cordial coöperation from the superintendents throughout the country as I pay visits to their various cities and towns.

REMARKS BY MR. LEWIS M. HASTINGS.*

I was asked to say a few words about ancient times and what has happened with the water works in the past, and especially to note any changes that I have run across, so that I present this for what it is worth.

To the young or middle aged man, a look ahead into the future of nearly half a century seems a long and almost endless period, but to the person who has passed over that time, as I have done, and whose "hair has been bleached by the snows of many winters," the time seems incredibly short and perhaps uneventful. If the faculties are unimpaired and the memory is still retained, a little thought will bring to mind many experiences which have given sincere pleasure and have been the means of getting useful information, or the chance of making pleasant acquaintances.

Among the many instances of this kind which I have enjoyed, I rate very highly the meetings which have been held by this Association. This is particularly so with reference to the annual meetings held in the various parts of the country. I can honestly say that some of these meetings have been of the most useful and informative character as regards water-works matters. As I look back on the years that are gone I remember with especial pleasure and profit various trips to Portland, Syracuse, Buffalo, Albany, New York, Rochester, Philadelphia and Hartford. At most of these meetings the attending members were given the opportunity to observe the salient parts of the different means of collecting, storing and distributing the water supplies of the various places.

Next to the process of securing an adequate supply of pure water, perhaps the most important feature of water-works engineering is the conveying and distribution of the supply already acquired. In this field a marked change has been noted in the material and methods applied, as the years that have gone on have added experience and increased knowledge about them. It is to this subject that I wish to call your attention very briefly today, and to illustrate it by a few examples of different materials which have been used in the making and carrying on of the water system of the city of Cambridge.

In the first periods of this science of water distribution many of the simpler and softer materials were used for pipes or conduits. Some of them were like lead, and we read in Roman history that one of these materials

*City Engineer, Cambridge, Mass.

was very extensively used in the layout of the system in use in Rome some twenty centuries ago.

Mr. Clemens Herschel, a former member of this Association and of the Boston Society of Civil Engineers, made extensive studies of this subject, and in 1898 he published a very interesting account of the work as he had uncovered it in Rome. He also gave to the Boston Society of Civil Engineers a piece of lead pipe of Roman manufacture.

In the early days in this country, wood, being more plentiful than metal, was very naturally and extensively used, and we have several samples of wood pipe or hollow logs which have been used in the classic city of Cambridge.

On April 13, 1837, nearly a century ago, a charter was granted to the "Cambridgeport Aqueduct Company" to construct a water works, and finance the works with a capital of $30 000. Water was taken from a natural spring in Somerville, and the water was carried to different parts of the city at that time by hollow log pipes, of which we have a sample. It is quite an interesting sample of an ancient method of carrying water through wood and it is quite remarkable to see how well preserved and sound this sample of wood is that has been nearly one hundred years underground.

I am also informed that the early pipes from Jamaica Pond for the supply of the city of Boston were of wood. Some large installations of wood have also been made in the West in recent years.

Since about 1850 vast amounts of cast-iron pipe have been used in this country with generally good results. Under some conditions, rapid corrosion and tuberculation has taken place, as is shown by some of the samples of cast-iron pipe taken from the Cambridge works. An improved quality of pig-iron, more care in molding, and good protective coating will undoubtedly lessen these defects and improve the life of the pipe.

The use of rolled steel plates as a material from which to make a water pipe was begun in about 1890. At first the use of steel as a material from which to make water pipe was looked upon with doubts by many. It was feared that the greater sensitiveness of steel to injurious action of certain chemicals in the ground would greatly shorten its life. It was quickly found, too, that electrolysis, the electrolytic action set up by stray currents of electricity, even if of low potential, upon leaving the pipe caused a pitting of the steel plate, and if continued long enough leaks would eventually appear. This condition was very much more general in sections traversed by electric car lines. This result has very generally been overcome by the use of a strong enamel coating and a better general bonding of the electric car rails, so that a great part of the stray or spent current is returned to the power house.

Owing to the lower cost of steel pipe, especially of the larger sizes, its greater tensile strength and lesser liability to fracture, and the ease with which the joints and special fittings can be made and the joints in the main pipe welded, many large installations are now being made of steel plate.

A rather instructive and interesting sample of the use of steel for a 40-inch main comes from the Cambridge Water Works. It was taken from a pipe 24 000 feet long, running from the pumping station at Fresh Pond to the Payson Park Reservoir in Belmont, and from the reservoir to Cambridge Common near Harvard Square, in the heart of the city. It was laid in 1895. Shortly after the line was put into service, several leaks occurred and the pipe was found to be pitted by electrolysis. Those breaks were repaired by banding the pipe and then by caulking with lead. The rails of the car line were then carefully bonded to send the stray current back to the power house. Since then very little pitting has been found. The recent installation of a new cast-iron pipe line in the eastern section of Cambridge made it necessary to cut into this 40-inch main at Cambridge Common and connect to it the new 30-in. pipe. A 30-in. disk of 5/16-in. plate was cut out of the steel pipe. The condition of the steel plate seems to show that the thirty-six years of service on this steel pipe have not seriously damaged the metal and that it is in good shape for many years of service.

Another method of constructing these pipes is quite recent. A new combination of materials has been offered for water-pipe purposes. It consists of a fine grade of cement concrete, heavily reënforced with steel wire mesh and electrically welded. This has been used in some large installations in this country and so far has proved very satisfactory. It is claimed to be lower in first cost than the all-metal pipe; it gives a high coefficient of discharge and has the advantage of greatly reducing the effects of metallic corrosion. It will be interesting to see what defects if any, develop in time.

From this very brief résumé it seems that water works men have now a wide variety of material from which to select the kind of pipe best adapted to the requirements of any particular situation.

REMARKS BY MR. JOSIAH S. MAXCY.*

It is interesting to look at living conditions when this Association was formed. Few places in Maine, my native state, had water-supply systems or sewers, and the serious annual toll of deaths by typhoid fever, dysentery and kindred diseases caused by impure water, impure milk, and lack of sewerage, was expected. It is hard for the present generation to realize that at that time little was done to correct it.

Of material things, bathrooms were few; electric lights were not in use; the telephone was hardly known; the typewriter had not begun its useful service; the automobile had not supplanted the horse; the flying machine was in the mind of Darius Green; and the radio and wireless had not been conceived. All these things, familiar to the child of today, were not in the vision of the early eighties. We have lost one interesting feature, the hand-power fire engines with enthusiastic volunteer crews, who when

*Treasurer, Calais Water & Power Company, Gardiner, Me.

exhausted from pumping were replaced by bystanders pressed into service by the Chief Engineer, with authority to fine any man who refused to aid; and the parades of red-shirted firemen (many hilarious) on gala days.

From 1885 until 1900 I was treasurer and manager of eight different privately owned water companies in Maine and one in New Brunswick, and director of three in Wisconsin, serving twenty-two different communities.

It is interesting to know how I happened to go into an enterprise that changed the whole course of my business career. In 1884 I built my dwelling house in Gardiner, and installed a bathroom; it was the fourth or fifth one in a city of about six thousand population. I put in a pump to force water to the attic for the benefit of this bathroom, and employed a man to do the pumping, but his temperance habits were such that the tank frequently ran dry. I then induced my woman cook to supply the man power, but she tired of the exercise.

That fall I visited Providence, R. I., became acquainted with James J. Newman, a water works contractor, rehearsed my troubles, and asked his advice as to the best method of having water introduced into our city. He suggested that I go to Newport and see George H. Norman, who owned the Newport water system and was one of the best versed men on water systems in New England. I went to Newport, met Mr. Norman and told my story. He was a man of few words, and asked,

"How much population have you? What are your industries? Any source of water supply in your town?"

I answered his questions, and he said,

"Young man, go back and get me a charter from the state to build works, and I will give you $5 000 for it."

That started me in the water works business. What seemed good to Norman appealed to me; with two others we obtained a charter, and I never went back for my $5 000.

Conferences with Mr. Tidd, a hydraulic engineer of Boston, and with Edwin Darling of Pawtucket, who by the way was one of the original members of this Association, confirmed our decision to build the plant ourselves. The state granted us a broad charter, and as there was no Public Utilities Commission we had almost unlimited powers for the issuance of stock and bonds.

We were without funds to build the plant, and learned that a contract for hydrant rental from the city was essential to carry out our plans. We laid the matter before the city fathers, and discovered that none of them (and in fact few in our city) had seen a hydrant in use. We chartered a special car on the railroad, took the mayor, the members of the city government, and some friendly shouters to the nearest hydrant service, a trip of some sixty miles to Lewiston. At that time Portland, Bangor, Lewiston, and possibly Rockland were the only places in Maine which had adequate hydrant service.

This was in the middle of winter, when ordinarily running water in pipes was a question of a thawing process. Upon our arrival in Lewiston, the fire department was called out, and threw water over their tallest buildings. This demonstration convinced the city fathers of the practicability of having efficient fire-fighting systems at different points, instead of hand engines and neighbors' wells.

Following the demonstration at Lewiston, the city government voted us a twenty years' contract, for fifty hydrants at $2 500 per annum. While it assured the building of the works, it was a good trade for the citizens; because of the service we furnished through the hydrants there was a yearly reduction of $10 000 in insurance premiums in the city.

The building of the plant and subsequent operation were so successful that, with several wealthy and influential business associates, we obtained charters and built works at Waterville and Fairfield, Calais, Madison, Dover and Foxcroft, and Richmond in Maine; at St. Stephen and Milltown, New Brunswick. By purchase we obtained the systems in Bath, Brunswick and Caribou.

Many of these plants, particularly those operated by water power, proved profitable. The Caribou works were a sad story; built by another party, without proper engineering. Many difficulties occurred, and we suffered a large financial loss. There were other losses even more serious than this.

The debt limits of the various cities and towns prevented their building, or purchasing our plants, until an astute lawyer in one of our cities conceived a plan whereby a portion of a municipality, or of several combined, could form a Water District, and issue its bonds solely for the purchase of water systems, without affecting their previous debt. Under this plan all of our works except Calais and one other were taken over.

At the time our charters were obtained and the several works built, there was no Public Utilities Commission in Maine, and we could act at our pleasure in the issuing of securities, yet I am glad to state that when the plants were taken over as Water Districts, impartial appraisals gave us values greater than securities issued on our works.

Strangely enough, while my connection was with privately owned plants, I always felt that such a service should be rendered by the communities themselves, and we never opposed their taking over the plants. Naturally we tried to obtain what we thought was a fair value; in two instances we traded with the towns without a public appraisal. All of the plants taken over have proved profitable investments for the communities.

For several years we had as our General Superintendent Henry W. Rogers, one of the four charter members of this Association, a man of highest integrity and ability, who by his knowledge and advice as to our needs was of great assistance to us.

While we cannot contend that we built our plants for philanthropic

reasons, we feel sure that by our introduction of pure water we were largely instrumental in stamping out water-borne diseases. We are glad to believe that by our business ventures health conditions were greatly improved, and many lives were saved.

REMARKS BY PROFESSOR DWIGHT PORTER.*

The topic that was proposed to me was "Changes in Water Works Practice in the Past Forty or Fifty Years," which is rather an extensive field to be entered by one who has not been directly in the water works business.

Let me simply allude to one or two practices of former days that come to my mind at this time. One of them is that at the period of my early membership in this Association we were wont to hold our meetings in this very room of the Brunswick Hotel in which we have met today and from which we have been absent for many years, and that in those days we often were ushered into the dining room with music. There were several members — I don't know their names—who were good musicians, and whose entertainment has always remained a pleasant feature in my memory. Perhaps others of the older members recall this custom.

Another practice, probably unique, not a part of my own experience, and having only remote connection with water works, has come to me from persons who were in a position to know. I am a native of Hartford, Connecticut. My wife was a native there also. Her father was Mr. George Marsh, who had a brother Seth. Both were civil engineers. After railroad engineering in New York state and beyond, then often alluded to as "Out West," they returned to Hartford and entered the department of the City Engineer, perhaps then termed City Surveyor. George, my father-in-law, was a Republican. Seth was a Democrat. In due time it came about, I have been told, that when the Republicans were in control in the city, George Marsh became City Engineer, and Seth his Assistant. When the Democrats were in control Seth was the Engineer, and George the Assistant, a rather happy family arrangement. Both were active in the construction of the first storage reservoir of the Hartford Water Works, which was known as Storage Reservoir No. 1. This has since come under the charge of our member, Mr. Caleb M. Saville, who, as you know, has for years been at the head of the greatly enlarged water-supply system of Hartford, and now is Manager and Chief Engineer of the Metropolitan project for Hartford County which is in process of development.

*Massachusetts Institute of Technology, Cambridge, Mass.

REMARKS BY MR. J. CLIFTON WHITNEY.*

I was a little apprehensive, when the President started his introduction of those taking part in the symposium, that he might repeat the words of Daniel Webster in 1825 at the laying of the cornerstone of Bunker Hill Monument addressing survivors of the battle—"Venerable men, you have come down to us from a former generation."

I am reminded of the ideas they had years ago in regard to bacteria and the skepticism with which the germ theory of disease was regarded by a great many. There was a member of the board of aldermen who used to stray in on me once in a while with advice along certain lines. At one time he had been the head of the water department in a large New England city, and at some period in his existence had been in business in India. As proving his conviction that there were no such things as bacteria he instanced the case of the water supplied to the average little village throughout India, stating that most of them were located on a hillside just above a small pond. Of course they located there because water was available. All the drainage of the village naturally trickled into that pond, the women did their laundry work there, and then wound up by getting the town's drinking water from the same source. As the people seemed to live, this alderman took it for granted that it proved there was nothing whatever in this theory of water pollution by bacteria.

Mr. Maxcy's mentioning Mr. Norman reminds me that once I walked into his pumping station at Newport, when that city was having one of its periodical disputes with Norman and trying to get the works away from him — which, by the way, they never did — and I stayed a few minutes, asked some questions and walked off. When I had got a half mile away a buggy came up behind me, a man stepped out and inquired if I had just been to the pumping station, saying Mr. Norman would like to see me there. He said if I had any spare time, he would drive me back. Evidently Mr. Norman believed me to be a spy in the employ of Newport who was sizing up his plant and getting information for use against him.

You know you can get expert testimony on any side of any question without any trouble, and when the city of Gloucester was fighting Norman in an attempt to acquire the works, a very eminent civil engineer — now deceased — who was on the stand when I happened in on some other case, testified that the cement-lined pipe, of which the entire distribution system consisted in Gloucester, was, in his opinion, in better condition after being in twenty years than it was when installed. It seemed to me that Norman got his money's worth out of the engineer that time.

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THE BROOKLINE WATER WORKS AND F. F. FORBES.

BY M. N. BAKER.*

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From the day that surveys for the water works of Brookline, Mass., were begun late in 1873, until the present time, Fayette F. Forbes has been connected with the works, first as assistant to the designing and constructing engineer, and since completion of the works in 1875 as superintendent and engineer. It seems safe to say that both in length of service and in variety, importance and excellence of the work done under his untiring supervision, Mr. Forbes' record is unsurpassed in the history of water works in America or abroad. The outstanding feature of his career is his pioneer work in the study of microörganisms in underground water, the tastes and odor-nuisances they create and ways and means for their control, the latter culminating in the construction of covered reservoirs. Years later, iron and manganese troubles were met and conquered by the construction of an aëration and filtration plant. By these means of dealing with tastes, odors, iron and manganese, by extending filter galleries and adding wells, by doing pioneer work in waste control, Mr. Forbes made it possible for Brookline to continue for half a century its sole dependence on water from underground and its almost complete sufficiency of that source to date — a rare thing for a constantly growing municipality. These and many other experiences and accomplishments of this veteran in public water-supply engineering and administration will be reviewed more circumstantially in this paper, which will be confined chiefly to problems of quantity and quality of the water supplied to Brookline since the middle of the year 1875.

Few Water Works in 1870. The population of Brookline by the Census of 1870 was less than 7 000. Few towns of that size had a public water supply at that date. Actually, there were 243 works in the United States and eight in Canada at the close of 1870, and many of these were small gravity systems.

Beginnings at Brookline. At a special town meeting held on May 2, 1871, it was voted to create a committee of five on "supplying the town with water." One of the five was Edward S. Philbrick, an engineer with an office in Boston and a residence in Brookline, who soon after was appointed engineer to design and construct works for the town. A report by this committee, dated January 23, 1872, was followed by the creation of a "joint committee" on March 25 following, which was instructed to report on a possible supply from Boston and [or?] adjoining towns. The report of the second committee was submitted to a town meeting on

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February 6, 1873, ordered printed and distributed for consideration at an adjourned meeting on February 27. The joint committee submitted a report by Shedd & Sawyer, civil engineers; advised the town to take a supply from the Charles River (under Chap. 343, Laws of 1872); and proposed that three water commissioners to construct works be chosen by the town meeting, with authority to issue script to pay for the works. Apparently the voters were not yet ready to commit the town to any plan, for in September, 1873, a "Committee Appointed to Examine the Sources of Water Supply" submitted a report by Clemens Herschel in which he reviewed possible sources of supply and advised that the town take the "waters of Massapoag Pond" for which, apparently, the town had no authority.

After nearly three years of investigation by others and themselves, the commissioners on a new water supply accepted an offer of engineering services made in November, 1873, by Edward S. Philbrick, and appointed him "chief engineer of the water works of the town of Brookline," at a salary of $4 000 a year. Out of this Mr. Philbrick was to pay a principal assistant, "who is to be a person of experience, who shall devote his whole time to the work." This assistant, Mr. Forbes states, "was a Mr. Howland."

Mr. Forbes and His Career. Fayette F. Forbes was born in Buckland, Mass., May 9, 1851. How he became connected with the Brookline Water works may best be told in his own words, taken from a letter to the present writer, dated October 29, 1931.

> Shortly after leaving Williston Seminary I was employed in an engineering party making surveys for the Holyoke Water Works. When these surveys were finished I was employed by Mr. E. S. Philbrick of No. 12 West Street, Boston, who I think was a state engineer at that time. I was employed as a rodman in an engineering party, making surveys for the re-location of the Troy & Greenfield Railroad between Hoosac Tunnel and Greenfield. When this work was finished Mr. Philbrick placed me in the engineering department of the Boston & Albany Railroad, which had charge of all engineering work in Boston and on the railroad as far as Worcester. On Nov. 26, 1873, Mr. E. S. Philbrick was appointed to the position of engineer for the construction of the Brookline Water Works. On Dec. 9, 1873, Mr. Philbrick transferred me to the surveying party which made surveys for the Brookline Water Works. I was employed on this survey and construction of the works until late in the fall. As all work on the Water Works stopped during the winter, I worked in the engineering department for the Boston Harbor Commissioners, giving line for the sea-wall on the South Boston flats. Early in the Spring, I came back to the Brookline Water Works where I have been ever since. I might say that I have never been out of work one single day since I first was employed by the Holyoke Water Works. I took some evening courses at the Massachusetts Institute of Technology under the late Professor Lanza.

Becomes Superintendent in 1875. Thus began Mr. Forbes' long career at Brookline during which he has almost literally built himself into the

water works. On May 27, 1875, the first consumer was supplied with water, and on July 28 the fire department was notified that it could use the hydrants. Meanwhile the construction commission accepted Mr. Philbrick's resignation as chief engineer and appointed him "temporary superintendent" at $1 500 a year, beginning July 1, 1875.

In the context it is stated (final report of the construction commission, December 3, 1875) that: "Mr. F. F. Forbes [not mentioned before] was also employed to superintend the putting in of services to let on water, etc. at $3 per day." The following spring, the town meeting created a water board of three members and turned the works over to it for operation. At its organization meeting on April 20, 1876, Mr. Forbes was appointed "superintendent of distribution" at $1 000 a year. This title appears to have been used because on the same day the board appointed Richard J. Flinn as "engineman" at $24 a week (like Mr. Forbes he had worked on construction) and "employed" Charles D. Lincoln as clerk and water registrar at $500 a year. Such were the modest salaries paid in 1876. It was not until the board's second annual report (1876–77) that Mr. Forbes and Mr. R. J. Flinn rendered an account of their services, signing as superintendent and engineer respectively.

Ever since then Mr. Forbes' name has appeared in the annual reports as superintendent, but he has really been engineer as well as superintendent, at least since early in 1876. In addition, he served as clerk and registrar during two or three vacancies in that office, prior to the appointment, on May 3, 1892, of Z. R. Forbes to that position—which he has held ever since. For some three years before that time, Z. R. Forbes had served as "superintendent's assistant," designated in the report for 1889–1900 as "in charge of draughting and inspector of meters." R. J. Flinn continued as pumping engineer until a short time ago.

The Original Works. When the Brookline water works were put in use in 1875 it consisted of a filter gallery near the Charles River; a gravity conduit of "stoneware" or tile pipe leading to a steam pumping station; a cast-iron force main; and a distributing reservoir; distributing mains mostly of cast-iron; and house services of tar-coated wrought-iron pipe. The population was perhaps 7 300 (6 650 in 1870; 8 057 in 1880). The water pumpage for the first full year of operation (ending January 31, 1877) averaged about 340 000 gal. a day. Of 776 premises supplied at the close of the year, 713 were residences; 27 stores; 15 greenhouses; eight stables; two billiard halls; one bakery; ten public buildings. Among the fixtures were 573 water closets; 269 wash bowls; 324 bathtubs; 183 hose attachments. Only four meters were in use. Of 19.3 miles of pipe classed as distributing mains at the beginning of 1878, nearly two miles ranged from 2-in. down to ½-in. in diameter, and there was no 4-in. pipe.

Having outlined the history and character of the Brookline water works, and Mr. Forbes' connection with the plant, the more unusual elements of the works and problems which they have caused will be given

consideration, each in chronological sequence, chiefly as presented in the annual reports of the board from 1876–1877 onward.

Filter Gallery and Wells. The original filter gallery was located 100 to 300 ft. from the Charles River, on a ridge of land surrounded by marshes. A trench 4 ft. wide was dug in clean, coarse sand and gravel to a depth of 6 ft. The trench was walled with dry rubble to a height of 2 ft., then covered with a semi-circular brick arch 8 in. thick. Because of a peat bog from which it was not desirable to take water, the gallery was built in two stretches, 451 and 250 ft. long, connected by 389 ft. of 24-in. "stoneware" (vitrified clay) pipe, with cement joints. In 1878, it having been found that a portion of the longer gallery had been made useless because of a fall of the arch, choking the gallery with debris, an extension of 161½ ft., 6 ft. wide and 6 ft. high in the center, was made, after plans by Shedd & Sawyer, of Boston.

Canal Dug to Increase Gallery Yield in Emergencies. In June, 1880, the Charles River fell 7 in. below its previously recorded minimum level. The galleries yielded not over 1 m.g.d., and the consumption exceeded 1.2 m.g.d. On the advice of Gen. George S. Greene, a canal was dug 30 to 50 ft. from the river, with its bed 3 ft. below the water in the stream. The report of the water board for 1880–1881 says . . . "There was no sign of water finding its way from the river into the canal until the bank of the river was cut . . . showing that the bed of the river is so thoroughly cemented by the accumulation of sediment as to be practically water tight." The canal increased the yield of the galleries some 0.3 m.g.d.

Galleries Extended. Early in 1882, the water consumption having increased from 123 m.g.d. in 1876 to 180 m.g.d. in 1881 "while at the same time the yield of the filter galleries has sensibly diminished," the water board declared that extensions of the gallery from time to time would be necessary. It also said that the water from the river was so inferior to that of the filter galleries that the river water should be used only as a "last resort." It may be interjected that the average pumpage in 1881 was 0.477 m.g.d. To meet this situation, the report for 1883–1884 notes that a trench 220 ft. long had been dug as an extension to the filter gallery and that in it had been laid "Akron pipe" with open joints — from the salvaged portion of the 24-in. stoneware or vitrified clay pipe originally connecting the filter gallery. In his report for 1881–1882, Mr. Forbes did not mention this extension, but he said that the gates admitting water from the river to the canal had been opened during the year.

Pumping Schedule Changed. To cope with the growing water consumption and diminishing yield of the filters, and also with troubles from tastes and odors, the pumps were sometimes operated 16 hours a day — and later for 24 hours.

Wells Driven to Supplement Galleries. An additional supply having become imperative, the 1888–1889 report of the water board records that the town had accepted a legislative authorization to take more water

from the vicinity of its filter galleries and had bought 23 acres of land for that purpose but had not yet decided how to use it. A year later the board recorded that it had been authorized by a town meeting to add to the water supply, had bought 60 more acres on the far side of the Charles River, that 24-in. pipe for a river crossing had been purchased and that laying it would be hurried the coming season, with Mr. Forbes as engineer. During 1891–1892, 42 tubular wells were sunk. Still more wells were completed in October, 1894.

The filter gallery and its extensions, supplemented at times by diverting river water to the canal dug alongside it, supplied Brookline about 15 years before the first group of wells was brought into use. That the water board was satisfied with underground water, notwithstanding tastes, odors, and other troubles to be sketched further on, appears from its report for 1895–1896, which states that the board was "strenuously opposed" to being included in the Metropolitan Water District and declared that the Brookline supply "is one of the best in the country."

Another Filter Gallery Extension. Consumption continued to press closely on gallery and well yields and late in 1899 the town meeting voted to ask legislative authority to take an additional 2 m.g.d. from the vicinity of the Charles River. The State Board of Health gave its approval to the extension and in January, 1900, a bill authorizing the extension was introduced in the legislature. In his report for the year 1906–1907 Mr. Forbes remarks that the driven well system was practically completed 13 years before and that the only extension to it since made was eight wells near the pumping station. In its report for the calendar year 1910 the water board stated that tests having shown that an extension of the driven wells would impair the quality of the supply the money appropriated for more wells two years before had not been used. Instead, the water board had approved an extension to the filter gallery and recommended that the next town meeting appropriate $15 000 for the purpose.

This gallery extension was put in use in October, 1911, adding 450 ft. to the 922 ft. already in use. The 1911 report of the board describes the old galleries as East and West, 431 and 491 ft. long, respectively, with dry stone walls 2 ft. high, arched over with brick. The location of the new gallery is described by the board as beginning at the west end of the east gallery and extending along the ridge between the two old galleries. Mr. Forbes said in his 1911 report that in constructing the gallery a trench 16 ft. wide was dug, with its bottom 8 ft. lower than low water in the Charles River. The bottom of the trench was covered with 1 ft. of screened gravel. Then side walls 4 ft. apart were built, standing on the gravel. When these were 2 ft. high another foot of gravel was placed between the walls and the excavated space outside the walls filled to the top of the walls with screened gravel. An arch was then built from wall to wall and the space above the arch was filled with selected material. The walls were of reinforced concrete, in the lower part of

which were embedded three rows of drain pipe, one above the other, forming 2-in. inlets for the ground water.

A Hot Dry Year Makes Additional Supply Necessary. Immediately there followed an extremely hot dry year (1912). This brought the water consumption, on some days, to 5 m.g.d., which was all the town had authority to take from the Charles River. (Wherever the subject is mentioned in the reports of the board it assumed that all the water taken from the Brookline galleries and wells was diverted from the river.) So pressing was the need for more water that on December 30, 1912, the town voted $9 600 to afford temporary relief by an extension of the galleries and wells. At the same time it was voted to ask the legislature to authorize the diversion of more water from the river. The legislature went so far only as to give the right to as much of 3 m.g.d. additional as might be approved by the State Board of Health.

For some years after 1912 the reports of the water board are more concerned with the iron-and-manganese troubles described later in this paper than with an inadequate water supply.

New Wells Added and Old Wells Renovated. In his report for 1921 Mr. Forbes stated that some additional wells that had been driven several years before but never used were connected up in 1921, adding materially to the supply; and that 50 of the old wells had been redriven and 22 temporarily repaired. The 1924 report of the board indicates that the State Board of Health had restricted Brookline's latest grant of right to take more water from the Charles River to 3 m.g.d. from December 5 to June 5 and during the rest of the year to an amount dependent on the monthly rainfall on the drainage area of the river. This restriction was based on the opinion that otherwise injury might be done to other towns. The state board advised Brookline to enter the Metropolitan District System.

Brookline Joins Metropolitan District But Draws Little Water From It. As already noted, the water board had gone on record in its report for 1895–1896 as "strenuously opposed" to being included in the Metropolitan Water District." It kept out and continued to do so for about twenty years, but in the face of the growth of water consumption and the restrictions on taking more water from galleries and wells near the Charles River joining the district at last became necessary. This the water board did with great reluctance, pointing out in its 1924 report that joining the district would mean an initiation fee of $40 000, together with a yearly assessment of $91 000, less $55 per m.g. credit for whatever water the town obtained from its own source of supply. On December 24, 1924, the town voted to join the Metropolitan District. Apparently no water was so taken for more than three years. The 1929 report notes further that since May 1 of that year it had been necessary to draw a small amount from that source each week, but the estimated total (no meter yet set) was only 25 m.g. In July the Charles River was the lowest for many years,

so that much more water than usual was pumped from the stream to the "open filters" which allow the river water to fill the ground adjoining the galleries and wells. The amount of "Metropolitan" water drawn was 114 m. g. in 1930 and 73 m. g. in 1931.

Tastes and Odors Cause Early Trouble. The history of the Brookline water works, as thus far sketched, has been confined chiefly to the source of supply in its natural state, leaving early and continued trouble with tastes and odors for separate consideration. That an underground source of supply, with extensions from time to time, should have been made to serve constantly growing Brookline for the half century before it joined the Metropolitan System is a remarkable fact in the history of water works, as is also the small amount of water taken from the district for years afterward.

The development and maintenance of the filter galleries and wells, important as they were, caused only a small part of the problems Mr. Forbes met and solved. Had he not kept consumption down by early studies of waste and by the introduction of meters, the consumption and waste would have outrun additions to the galleries and wells long before it did. More significant by far is the fact that if Mr. Forbes had not done even more striking pioneer work with the microscope in studying the cause of the tastes and odors in his underground supply, increased the pumping period when algæ were rampant so as to deliver water direct to consumers without exposure to the light in the reservoir, showed the advantages of covering the reservoir and carried out that job, and, later on, built aërators and filters to remove iron and manganese from the water the underground sources would have been abandoned as intolerable long ago. The conquest of taste and odors and of iron and manganese will be considered before waste control is taken up.

First Complaints of Quality of Water. It was not until the third annual report of the Water Board (1878–1879) that mention is made of the quality of the water being supplied to Brookline. In that report some complaints are noted but the reason for them is attributed to the entry of swamp water into the vitrified clay conduit. The next mention of complaints is in the report for 1885–1886 in which the water board states: "Some few complaints have been made at various times of the peculiar taste or smell of our water, but all of them have occurred since November 1, the date we stopped the 16-hour daily pumping, that has been the rule the past two summers." The board then remarks that it is general experience that in stored "spring water" growths occur. It then mentions algæ and says that this growth was "found in our reservoir on Fisher Hill in large quantities within six days after it had been drawn off and cleaned out to the bottom stone. In fact, the growth is more rapid after such cleaning, for the reason that a fresh crop of germs have been introduced with the new water supply, and we have destroyed a multitude of small fish which feed upon this substance and thus aid in keeping down the

growth." From May 1 to November 1 in both the years 1884 and 1885, when the pumps were being worked 16 hours daily, the report says, "thus giving the consumers within those hours water direct from the galleries . . . no word of complaint was heard of the quality of the water."

From this experience the board inferred that running the pumps 16 hours a day and keeping the water from exposure to sunlight was an effective way of forestalling complaints of quality. The board rather timidly suggested pumping 16 hours a day throughout the year, thus keeping the reservoir full for emergency use only, at an extra operating cost of $75 to $80 a month, but it quickly added that as the complaints regarding quality were so few it did not "feel justified in recommending this increased appropriation." Mr. Forbes, whose early contributions to the reports of the board were generally brief and extremely modest, made no mention of this trouble with tastes and odors or the extended pumping period used to prevent complaints.

In its report two years later (1888–1889) the board referred to conclusions of a special committee that had been appointed to consider additional sources of supply and had recommended an added draft from existing sources. This committee declared that the present source of supply was in itself satisfactory but added that it "cannot be kept agreeable to the taste and smell" and therefore is not acceptable to the water consumers. The committee stated that the only remedies were covering the reservoir or pumping continuously 24 hours a day, at the same time shutting off the connections between the reservoir and the distribution system. Continuous pumping was dismissed by the committee as impracticable. As an argument for covering the reservoir the committee called attention to the fact that roofing the high service tank had ended all complaints from water consumers drawing water from the high service distribution system.

In this same report for 1888–1889 Mr. Forbes mentions for the first time trouble with taste and odor:

> The reservoir was drawn off and washed out in July (1888). The same cause which made the water unpleasant to the taste, still remains, and is owing wholly to algæ growth. Frequent microscopical examinations of the water are made and recorded, for the purpose of detecting any change in the growth, resulting either from a different manner of pumping into or drawing from the reservoir, or other causes, to which these growths are subject . . . Without present knowledge, nothing but a total exclusion of light can wholly stop this trouble.

It seems reasonably safe to say that the lines just quoted are the first ones ever printed in which a water-works superintendent records his own use of the microscope to study the causes of tastes and odors occurring in underground waters stored in open reservoirs and points out that the only way to prevent the trouble was to cover the reservoir. These microscopical studies were begun in 1887. Of three papers on treating odors and related

matters, read by Mr. Forbes before the New England Water Works Association, the first one appeared on p. 196 of Vol. IV of the JOURNAL (1889–1890) and was entitled "Algæ in Reservoirs and Ponds." Earlier than that Mr. Forbes read a paper on the same general subject before the Boston Society of Engineers, but did not permit its publication because the ideas expressed seemed too novel at that time. This earliest paper was accompanied by colored photomicrographs made by Mr. Forbes.

In reverting to tastes in its report for 1889–1890 the water board said that up to November 1, 1889, the water had been less objectionable than for several years previously but that on that date, as also for the four years past, operation of the low-service pumping station was cut down from 16 to 12 hours. Quoting now from the report:

> The complaints which poured into the water board's office from all parts of the town were more general and more pointed than at any time since the works were established. Although the amount of water which got into the distributing mains was comparatively small, still its character was so pungent and intensely offensive to the taste and smell, that all the water was rendered entirely unfit for domestic use.

To meet this condition the pumping schedule of 16 hours a day was resumed, but "finding that this did not remove the difficulty, on January 8, 1890, 24-hr. daily pumping service was ordered, and this has been continued down to the time of preparing this report." After mentioning the impossibility of continuing the pumping service 24 hours a day during the coming period of low water and high consumption, the report says:

> There seems, therefore, but one radical cure for this difficulty, namely, a covered reservoir, and the water board would therefore urgently recommend that immediate steps be taken to this end. . . . It has been discovered by the microscopical examinations made by the superintendent, that a new species of vegetable growth was appearing in the water not before found there, and that it was rapidly changing the quality of the water to intensely disagreeable.

This last quotation refers to the time of the November shutdown of the pumps and the subsequent complaints.

Mr. Forbes takes up the need for the covered reservoir again in his report for the year ending January 31, 1890, as follows:

> As long as the water in the reservoir is exposed to sunlight, a total absence of all smell and taste cannot be assured. But, by careful study of the algæ life which causes this trouble, the number of days in which an unpleasant taste is present can be greatly reduced. Yet there are likely to be periods when the water from the reservoir will be more or less disagreeable to the consumer.

The vagaries of algæ growth are illustrated by the fact that in its report for 1890–1891 the board was able to state that "the quality of our water has been uniformly good throughout the year, even from the reservoir." The board then adds, "By close attention and frequent microscop-

ical inspection by Mr. Forbes, the nature and habits of the growth which affects the waters of our reservoir are being better understood, and their evil consequences guarded against in a measure." In the same report Mr. Forbes says that the water is all right when it leaves the filter galleries, but when exposed to the sun in the reservoir growths appear and impart more or less disagreeable tastes to the water. With our present knowledge it is impossible to keep all, or in fact a large part, of these minute organisms from open reservoirs. A continuous study, however, with the aid of the microscope, now extending over several years, has told us a great deal about them, and as a result of this knowledge, the town has received very much less unpleasant water than otherwise would have been possible . . . . But with all the progress which can be reasonably expected in this line of investigation, without doubt the ideal water supply must ever be looked for in a water drawn from uncontaminated filtering galleries and wells, or similar sources, and its purity and agreeable qualities preserved by storing the amount considered necessary in covered tanks or reservoirs.

In January, 1892, the water board records as it was closing its report for 1891–1892, "Asterionella, one of the most offensive of the algæ tribe, is very abundant in our reservoir . . . and an effort is being made so that little or none of that water shall get into circulation."

After all the warnings that had been given by the water board, and the trouble that had been experienced by the citizens of Brookline, a town meeting on October 27, 1891, created a special committee on extension of the water works. In its report (submitted in February, 1892) the committee reverts to a report of an earlier special committee in 1887 which had recommended the construction of a 3-m.g. covered reservoir, as already advised by Mr. Forbes. These recommendations were endorsed by the later committee.

At last the town was ready and willing to act. At a meeting in April, 1892, it authorized the construction of a covered reservoir on Fisher Hill. This reservoir was put in use on January 1, 1893. It was 91.33 ft. square at the bottom and was roofed with flat arches supported by brick piers. Two years later the water board reported that during the year 1894–1895 the water had continued to be "nearly, if not quite free from microscopic organisms and vegetable growth detrimental to its quality."

A few years went by with apparent satisfaction as to the quality of the water. The report of the board for 1901–1902 stated that there was no reason to expect any change in the quality or quantity of water from the galleries or wells, but noted the need for an additional covered reservoir and stated that plans for one had already been made by Mr. Forbes. Two years later the board reported that on recommendation of a special committee (which included in its membership Desmond FitzGerald, long a resident of Brookline) the town had authorized (December 30, 1902) the water board to build a new covered reservoir at a cost of not over $75 000. Construction was begun in March, 1903, and the reservoir was

put in use on May 16, 1904. Mr. Forbes, who designed this and also the earlier structure, describes the new covered reservoir as being located on the site of the original one built 30 years before. The new reservoir was covered by elliptical arches of concrete with a minimum thickness of 6 in., supported on masonry walls with brick and concrete piers. Mr. Forbes also stated that construction was done by day labor, by citizens of the town as far as possible; that no accidents occurred during construction; and that the reservoir cost $74 232 — $668 under the sum appropriated for construction.

To complete the story of covered reservoirs, it may be noted that one for the high service, with a capacity of 4 m.g., was begun in 1909 after plans by Mr. Forbes and was completed in 1911. It was 180 ft. in diameter, 23 ft. deep, built of reinforced concrete.

Iron and Manganese. An underground supply had been in use nearly 40 years before the reports of the water board mentioned trouble from iron and manganese. The subject is first noted in the report of 1913 in which it is stated that in common with other ground waters those supplied to Brookline have shown an increase in iron and manganese from year to year "until the amount of these minerals at the present time is sufficient to cause some complaint. The board has given this matter careful consideration for the past two years and caused studies to be made of ways and means of removing the iron and manganese with successful results." The report then mentions that an experimental plant was established in 1912 to treat the water by aëration, subsidence and coagulation and sand filters, the latter working at the rate of 5 m.g.d. (per acre?). This method of treatment, the report said, had been successful elsewhere but the cost had been "quite large."

In hopes of devising a less costly method of treatment the board employed Robert S. Weston in 1913 to make additional experiments. In accordance with his suggestion tests were conducted with coke tricklers working at the rate of 75 m.g.d., followed by a coagulation basin large enough to give a one-hour detention period and a sand filter working at 10 m.g.d. per acre. The experiments showed that this method was successful and that the cost would be much less than the one previously tested. In his report of the same year Mr. Forbes refers to the second experimental plant as having been built after sketches by Mr. Weston and operated until late in December, 1913. He states that the tests "proved conclusively that a large part of the iron, manganese and CO_2 could be removed without excessive cost." Mr. Forbes advised that a manganese-and-iron removal plant be built. After some delay the town appropriated $200 000 for the purpose. The 1915 report of the board states that in view of increasing amount of iron and manganese in the water, construction was started soon after the appropriation was made and weather permitted and that by cold weather all the concrete work had been done. The plant as built included coke tricklers to supply 10 m.g.d. to covered filter beds having

an area of about one acre; a settling basin and a 2-m.g. clear-water basin. Without giving credit to any individual the report states that the engineering department coöperated fully as to plans, lines and grades. The board takes pains to state that all the concrete work had been done "by day labor," as far as practicable by citizens of the town.

These men do not seem to have been as grateful as they might have been to the town for having the work done by day labor for the report of 1916 notes that a strike of laborers for higher wages had delayed work. The demand was not granted, and the labor supply available was so limited as to delay the work. Delays also occurred in the delivery of pipe by contractors, the installation of pumps, and because of difficulty in getting coke, the latter being due to the general shortage of coal. The first water was delivered to the town August 20, and by September 12 the whole plant was in use.

After four or five years of use, Mr. Forbes' report for 1922 states that "the filters continue to give excellent results, removing all the manganese and 95 per cent. of the iron." Again, in his report for 1927, Mr. Forbes remarks that "the filter continues to remove all manganese and most of the iron"; and this he repeats in his 1928 report. For 1929 Mr. Forbes reports that the tricklers, while still giving good results, "are getting more clogged through the entire depth of the coke. It has been necessary to use wash drills to keep them free enough to run water through them. This process breaks the coke to some extent, and one of the tricklers at least should be filled with new coke for the coming season."

Early Breaks in Short Line of Vitrified Clay Conduit. Noteworthy in the history of the Brookline water works is that in its nearly 60 years of service, few structural failures of any kind have been recorded in the annual reports of the water board. The first and only failure noted by the present writer in an examination of the long series of water-works reports, is a break in the gravity conduit between the filter galleries and the original pumping station that occurred about the time the works were first put in use, while Mr. Philbrick was still connected with the works and before Mr. Forbes became engineer and superintendent. This was a 24-in. vitrified clay pipe, designated at the time as "stoneware." In its final report the construction commission states that in May, 1874, it took into consideration the material to be used for this conduit. Brick was first proposed but was given up because of its great cost and length of time to build. On Mr. Philbrick's advice, the board voted on May 28, 1874, to use "Scotch pipe, with an internal diameter of 24 in." Two bids for construction were opened June 1. The lowest bidder failed to comply with bond requirements. At that time the attention of the commissioners was called to pipe made at Akron, Ohio. The commissioners stated in their report that they personally examined specimens of the pipe, then referred the matter to their engineer who reported "that the pipe was uniformly spoken well of by those who had used it, and that it was con-

sidered by them as good as the best Scotch, and that, in his judgment, it was strong enough for the purpose, and he recommended its use." On July 7 the board voted to use Akron pipe for the conduit and subsequently contracted for 3 450 ft. of it, 24 in. in diameter, at $2.45 per linear foot, delivered at the Spring St. railroad station. The pipe was delivered November 19, and final payment for it was made on December 17, 1874. The conduit was completed in the year just mentioned, before the work was shut down by "frost." When the water was let into the conduit is not stated, but the construction commissioners say that the pumping engine was set in motion for the first time on May 15, 1875; the first water users supplied May 27 of the same year; and the fire department notified on July 28 that it could use the fire hydrants.

On or about July 10, 1875, a subsidence of ground over the pipe was noted, and it was found that the conduit was broken for a length of about 5 ft. This was replaced by a plank flume. On making "careful search" a similar break was found. This was repaired in the same way. On August 11 the engineer reported all breaks closed but on August 26, the report of the construction commission states, "the conduit was found to be cracked to such an extent as to make it appear probable that the entire conduit would break in." The breaks were more serious where the foundation was "hard and immovable, than where it was of quicksand." The commissioners, therefore, were forced to the conclusion that the material itself was insufficient for the duty required of it.

On August 30 the commissioners voted "to advertise for proposals to cover the conduit and surround it with cement and rebuild the trench." Not satisfied with getting bids on only one method of restoring connections between the filter gallery and the pumping station, on September 8 the commissioners advertised for "putting in a wooden flume, of a pattern similar to that used in repairing the breaks in the conduit. The right to reject either or both bids was reserved.

To get engineering advice the commissioners engaged Joseph P. Davis, city engineer of Boston, and J. Herbert Shedd, city engineer of Providence. The report of each of these engineers is given in the final report of the construction. Extracts from each report follow:

[Mr. Davis, September 8, 1875] . . . many of the pipe have split lengthwise, and are so crushed down and distorted as to be useless, and must be replaced by some stronger form of conduit section. The failure does not seem to have been caused by any yielding or displacement of the foundation; but by want of strength in the pipes to resist change of form, when laid, as they were, upon rigid supports and subjected to a load. [Pipes] of American manufacture were used and as compared with the Scotch pipes they appear to be made of inferior materials, and not so well able to resist external pressure.

[Mr. Shedd, November 18, 1785] . . . [the] clay pipes . . . are too thin for that diameter [24 in.] in such a service. The thickness should be at least one-twentieth the interior diameter. I have used such pipes, of greater proportionate thickness, in equally trying situations, and consider them quite satisfactory for the purpose.

It would be interesting to know the shell thickness of these pipe and the depth and weight of their load.

On September 13, 1875, the commissioner voted to take up the conduit, "leaving the sheet-piling and platform, put in the year before, undisturbed," and to put in a wooden flume as recommended by Mr. Philbrick and Mr. Davis. Apparently the one formal bid previously received was accepted. The work was completed by November 5, 1875. Altogether 1 050 pieces of Akron pipe were found in good condition and put in storage — out of a total length of 3 415 ft. The total cost of replacing the conduit, including the preliminary examination and engineering, was $15 713.

The wooden conduit was abandoned in October, 1879, and in its place a 16-in. cast-iron force main was put in use. This was laid across the swamp from the filters to the pumping station and used temporarily as a suction pipe, 2 900 ft. in length. Soon afterward the pumps were removed from the original pumping station to one located at or near the filter galleries, the 16-in. cast-iron pipe line then being converted into a force main connected with the original force main leading from the first pumping station.

Early Studies of Water Waste. The small margin between yield of the filter galleries and water consumption, particularly in dry weather, led Mr. Forbes to go into the question of water waste early in his career as superintendent. In his report for the year ending January 30, 1882, he noted a study of consumption and waste in the early morning hours and a house-to-house inspection, the latter resulting in reducing leakage by 100 000 gal. a day, which Mr. Forbes put at half the total waste. He adds that this reduction "lasted for a short time only" and says further that "in order to keep the leakage at a small figure, a regular monthly inspection would be necessary."

Aside from the house-to-house inspection Mr. Forbes' study of waste included observations of the level of the water in the reservoir made at intervals from June to January, 1881–1882. A page of his report is filled with a table entitled "Record of Waste," showing the waste on 39 days distributed over the period mentioned, the observations having been made from 12 to 4 A.M. In commenting on these studies of waste, the water board, in its report for the year mentioned, says that as there was no manufacturing use of water in Brookline, there should have been little *use* of water from the reservoir during those morning hours. Based on the figures given by Mr. Forbes the board concludes that the waste each 24 hours was 210 000 gal. or 44 per cent. of the water pumped.

First Steps Toward Universal Metering. On November 14, 1888, there were only 156 meters in Brookline. On that day the town took the first steps toward metering all services. At the close of the next fiscal year (January 31, 1890) there were 576 meters in use, besides those in public buildings. An increased demand from consumers for meters was noted in the annual report for 1897–1898 where it is stated that about half of

the water takers were using meters and more than half of the water rates were for metered water. For that year the average daily consumption was 78 gal. per capita for the entire city, but only 44 gal. for those having meters.

Universal Metering System Adopted. On December 28, 1891, the town, on the recommendation of a special committee appointed nearly a year earlier, authorized the establishment of a universal metering system. At the same time this committee advised that all water used for town purposes be metered, but said nothing about the town paying for it. The number of meters set on January 31, 1905, was 2 849, compared with 4 091 service connections. Of these 2 612 were $\frac{5}{8}$-in. and 131 $\frac{3}{4}$-in. Metering went on speedily, for the water board report for 1905–1906 states that about 1 600 meters had been set since May of the previous year and that at the close of the year all water was being delivered through meters.

The water consumption for the year 1904–1905 was 98 gal. per capita, an increase of 7 over 1903–1904. The minimum per capita water consumption for the past 12 years had been 79 in 1896–1897 and again in 1897–1898. The maximum previous to 1904–1905 had been 92 gal. in 1901–1902. In his report for 1907–1908, after the universal metering system had been in use for two full years, Mr. Forbes said that the average daily per capita consumption had risen from 80 to 86$\frac{1}{2}$ gal. during that year but it had been a dry one. Had it not been for Mr. Forbes' early drive against water waste, continued until all services were metered, the underground supply would not have sufficed until a few years ago and still be the main dependence of Brookline.

Construction by Day Labor. Under Mr. Forbes and the water board of Brookline, day labor has been used on construction work more generally than has been customary elsewhere. In a letter to the present writer from Mr. Forbes dated October 29, 1931, the latter states that: "The works were built under contract, but for the last 50 years all our work has been done by day labor, except for the building of our first covered reservoir." [The reports of the water board note a few other minor exceptions.] The day-labor work has included the lining of service pipes with cement, practiced for several decades past — tar-coated iron services having been given up for lead in 1879, to be displaced soon by cement-lined pipe. The lining is now done in a two-story "service building" erected for that purpose and for storage from an appropriation of $30 000 granted in 1929.

Financial. Examination of the long series of reports of the board discloses a surprisingly small consideration given to financial questions, particularly not to the proper basis of charges for water delivered to consumers, private and public. In the annual report of the water board for 1898–1899 it is stated that for the first time in the history of the works the revenue from private consumers covered extension and maintenance accounts, salaries of members of the water board, the water registrar and superintendent, and also interest on outstanding bonds, and that with

the surplus of $14 857. This showing is credited to a heavy increase in water revenue combined with a reduction in water debt charges. On a private corporation basis, the water board says, if the water charged to public departments were paid for, the surplus just mentioned would be equivalent to 3½ per cent. on the capital investment. In one of the earlier annual reports, and also from time to time through the series, some mention is made of water supplied to schools and other public buildings and for other public purposes, but it is not clear to what extent any of this was ever actually paid for; very little apparently.

Many years later the special commission that recommended that the town join the Metropolitan Water System mentioned the fact that before 1918 water revenue paid annual operating and maintenance expense, interest on bonds and serial bonds as due, but that since 1918 the increasing cost of coal, iron, lead and all material and labor had created a deficit met by general taxation. The special committee advised that water rates should be amended to cover all the above charges and suggested an increase in the metered rate to 18 cents per 100 cu. ft. The town voted to increase the rate as recommended effective after meter readings of December, 1924. As recently as 1929 the water board noted a charge to the town of Brookline of $19 378 including $6 766 for school buildings and numerous other items that seem to cover everything in the way of public service except fire hydrants. Whether any of this was paid is uncertain.

This paper should not close without recording the remarkable vitality shown by Mr. Forbes throughout his career and particularly during the decade that has elapsed since he reached three score and ten. Years after most men of his age would have either given up work or at least delegated much of the responsibility of their position to others and confined their activities to short hours, Mr. Forbes continued to leave his home about seven o'clock in the morning, go to the water-works yards and start the gangs out on their work, then proceed to the pumping station and filter plant. He would then reach the water-works office in the town hall at least as soon as most of the other town officials began their day's work.

Acknowledgment. I am indebted to Mr. Forbes for checking through this paper, and appending this note: "No mention has been made of pumping engines. Our vertical triple-expansion pumping engine was the first one this side of Detroit, Mich. It is in good condition today." A view of this Allis pumping engine is shown in the annual report of the Brookline Water Board for 1893–1894. The report states that the pump was first started March 3, 1894, but not put in daily use until late in April. It had a contract capacity of 5 m.g.d., was guaranteed to lift 120 000 000 lb. of water 1 ft. high per 1 000 lb. of steam. Its cost was $26 000, including steam and water piping in the engine room. The annual report states that the guaranteed duty was exceeded in regular operation.

WATER CONSUMPTION DURING FIRES.

BY C. W. MOWRY.*

[*Read September 30, 1931.*]

As a starting point for our discussion of water consumption during fires, let us think of fire fighting as a race between the spread of the flames and the application of water. Just as in any other race, minutes, and even seconds, count. Usually the water wins at the start or soon afterward. When it doesn't, we have a 3-alarm fire, and occasionally a conflagration.

A single pail of water at the start of a fire may be of more value than a million gallons of water later on. If someone had thrown a pail of water on the blazing lantern when Mrs. O'Leary's cow kicked it over, it would never have caused the big Chicago fire of 1871.

In this race between fire and water, it is evident that the amount of water used will depend on how soon it is applied after the outbreak of the fire, whether or not it is applied on the burning material at the seat of the fire, and not wasted, and whether it is applied at a sufficient rate to drown the fire at the start.

Typical Fires.

To illustrate these points concretely, and to show the actual amount and rate of water consumption needed for fire fighting, I have selected some typical examples.

Fire Test at Washington, D. C. The first example illustrates the speed with which a building will burn without the application of water. In a portion of Washington where an entire city block was being razed, a unique fire test was conducted in 1928 by the U. S. Bureau of Standards. Two adjoining buildings were selected for the test. One was 75 ft. by 30 ft., five stories high; and the other was 75 ft. by 20 ft., two stories high. Both buildings had brick walls and ordinary joisted floors and roofs. Each had an open stairway and elevator shaft. There were few partitions, and there was nothing to obstruct the rapid spread of the fire thoughout both structures. To represent the combustible occupancy of an office or mercantile building, waste lumber was spread on each floor. Numerous iron safes were distributed throughout the buildings as they would be in actual practice.

About 5:30 o'clock one Sunday morning when weather conditions were favorable, the contents of both buildings were ignited simultaneously on the ground floor. Within five minutes, fire had spread up through the open elevator shaft to the top of the five-story building, and soon afterward, the entire contents of both buildings were involved. This is an illustration

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of the importance of the first five minutes in fire fighting. Within twenty minutes, the wooden floor joists were burning through and the safes began to fall. (See Fig. 1.) In twenty-eight minutes, a section of the front wall fell out, followed by portions of the other walls at intervals. In three-quarters of an hour after the start, most of the walls above the first floor had collapsed. At the end of two hours, both buildings were completely burned down.

FIG. 1.— FIRE TESTS AT WASHINGTON, D. C.
Ten to twenty minutes after starting fire simultaneously in first story of both buildings. No water applied.

Fall River, Mass. For our second example, let us consider what can happen in a city with an excellent public water system and a first-class fire department, when fire gets a good start before it is discovered.

In the business center of Fall River, Mass., fire was discovered in the first story of one of the vacant Pocasset Mills at about 6:30 in the evening of February 2, 1928. In anticipation of razing the plant, the automatic sprinklers had been taken out, and holes had been cut in the heavy plank floors for lowering machinery. Although the mills were located within two blocks of fire department headquarters, the fire had secured a firm foothold before being discovered. First-alarm companies were unable to check the spread of the fire into the upper stories of the 6-story stone mill. A general alarm was sounded seven minutes after the first. Hose streams could not be brought into action quickly enough in the crowded mill yard to stop the

fire, which jumped to adjoining buildings and continued to spread. Outside aid was called, eventually bringing assistance from twenty-one cities and towns which sent thirty-two pumpers and three hundred and forty-eight men. This is an excellent example of how modern automobile pumping

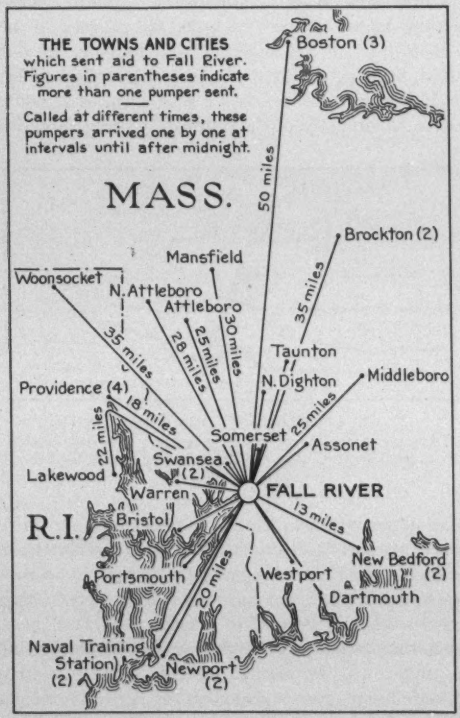

FIG. 2.— FALL RIVER CONFLAGRATION.
Twenty-one cities and towns sent 32 pumpers and 348 men to assist the Fall River apparatus, placing an extremely heavy demand on the public water system.

engines can quickly rush aid long distances to a city where a fire is out of control, and therefore how much greater the concentrated peak demand upon a public water system may be than it was before the advent of the modern automobile pumper. (See Fig. 2.)

The Fall River water works has three pumps of 10-, 8-, and 6-m.g..d capacity respectively. There are also four standpipes with a total capacity

of 5 300 000 gal., from which large supply mains lead to the center of the city where the normal pressure is about 70 lb. per sq. in. (See Fig. 3.) When the fire broke out, the standpipes were full and the 10-m.g.d. pump was supplying normal demands, then at the rate of 5¼ m.g.d. This pump was speeded up soon after the alarm of fire, and the 8-m.g.d. pump was started an hour later. After the out-of-town pumpers began to arrive and connect to the city mains, the heavy drafts exceeded the capacity of the two pumps which were operating, so that shortly after midnight the 6-m.g.d. pump was also started, bringing the total pumping delivery up to 24 m.g.d. The consumption, however, which reached a maximum of 21 600 g.p.m. or 31 m.g.d. exceeded the capacity of the pumps by 7 m.g.d., and had emptied

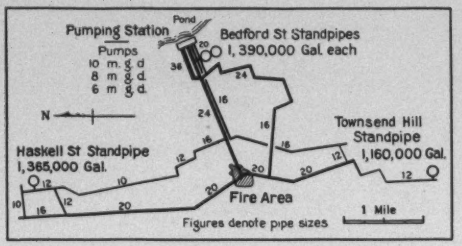

FIG. 3.— FALL RIVER WATER WORKS SYSTEM.
Diagram of main feeders, showing how the distribution system became a concentration system during the fire.

two of the standpipes by 6:00 o'clock the next morning. Fortunately the fire was under control at this time after having destroyed six city blocks with a loss of $2 550 000. All three pumps were kept in operation until the standpipes were refilled. It is estimated that over 20 000 000 gal. of water were used to fight this Fall River fire. (See Fig. 4.)

Although in the average city, only a fraction of 1 per cent. of the annual water consumption is used for extinguishing fires, yet the rate of consumption during a large fire may be higher than the capacity of the system as it was at Fall River. This is especially true today when out-of-town pumpers can be so quickly concentrated.

Spencer, Iowa. Pumpers were used in an unusual way to supplement the public water supply during a serious fire in Spencer, Iowa, June 27, 1931. This fire, which started in a drug store, swept through three blocks in the principal mercantile section of this town of 5 000 population, destroying 27 buildings with a loss of $750 000.

The municipal pumping station contained a 1 000-g.p.m., motor-driven, centrifugal pump, and a 600-g.p.m., steam piston pump. When the fire department pumpers of Spencer and other surrounding towns overtaxed the capacity of the municipal water supply, some took suction from

the spray pond of the municipal electric generating station, others were stationed at a pond in a gravel pit, and still others were located at a river about one-fourth mile south of the fire and pumped into street hydrants to augment the water supply during the fire. A maximum of twelve hose streams was used.

Warnings that the city water was polluted were posted throughout the town from Saturday evening when the fire occurred, until Monday afternoon when the water was again safe for use.

Dover, N. H. The fourth example will illustrate how much water may be required to fight a difficult fire which has a ten-minute start.

The Cocheco Cotton Mill at Dover, N. H., was five stories in height,

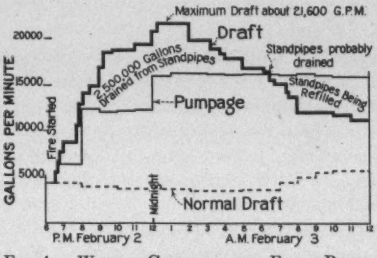

FIG. 4.— WATER CONSUMPTION FALL RIVER CONFLAGRATION.
Showing how standpipes helped to meet the peak demand of 31 m.g.d. or 7 m.g.d above pumping capacity.

with brick walls and heavy plank and timber floors and roof. It was equipped throughout with automatic sprinklers, having the primary water supply from the public mains, with a static pressure of 115 lb. per sq. in. and a flowing capacity of 1 500 g.p.m. at good pressure. Four fire pumps were also available on the sprinklers and yard hydrants, with a pumping capacity of 3 700 g.p.m.

At 6:30 one Saturday morning, while the sprinkler system was shut off temporarily to replace a sprinkler, fire started in the third story. It spread so rapidly that some of the operatives jumped from windows, some slid down ropes, and five were overcome and died. Only ten to twelve minutes elapsed before the sprinkler valve was reopened, and yet so many sprinklers had operated before the water was turned on that even the excellent public supply could not maintain adequate pressure, and all four fire pumps were started. When hose streams were brought into action, the pressure was too low for the sprinklers. The sprinkler valve was, therefore, closed and opened at three-minute intervals to furnish good pressure alternately to the sprinklers and hose lines. The temperature was below zero and fire fighting was difficult, but by noon the rapid progress of the fire

had been checked, although it continued all afternoon and night. At the beginning of the fire, the public reservoir contained about 1½ million gallons, and the water-works pump with a capacity of 2½ m.g.d. was started. After about eleven hours of fire fighting, the level of the reservoir was dangerously low, and the city water was shut off from the plant. In the first twelve hours of this fire, about four million gallons of water were used. The estimated total amount of water supplied from several sources during this fire is as follows:

City water	1 900 000 gal.
Fire pumps from river	5 500 000 gal.
Fire engines from river	800 000 gal.
Total	8 200 000 gal.

This experience is a good illustration of the advantage of having a practically unlimited auxiliary water supply from fire pumps at large industrial plants, even when there is an excellent city water supply, as there was in this case. The Cocheco fire also illustrates the danger of having automatic sprinklers shut off for even ten minutes. When sprinklers are supplied with adequate water at good pressure they extinguish fires more promptly and make less demand on a public water system than the use of large hose streams. Deputy Chief McLean of the Boston Fire Department while talking to the men at the fire college said: "We have reached the peak in fire fighting. We must look to fire prevention and the automatic sprinkler if we are to stop our wholesale burnings."

Indianapolis, Ind. The Indianapolis Water Company at Indianapolis, Indiana, has made large expenditures to reinforce its water supply system and increase the pressure and volume for public and private fire-protection service. For some time the Water Company has engaged in a campaign to increase the number of private fire-protection installations, and more than three hundred are now in service. Not a single large fire has occurred in Indianapolis during the past five years in any property well protected by automatic sprinklers. Practically every fire of any magnitude has occurred in a property the owners of which had been solicited unsuccessfully by the Water Company, urging some sort of private fire-protection installation.

Buffalo, N. Y. So far, we have been discussing the rapidity with which fire would burn, the consequent importance of applying water quickly, and the relation between the speed of application of water and the amount required. Another factor which influences the amount of water used on a fire is whether or not the water can be applied directly on the burning material at the beginning of the fire.

The 106th Field Artillery Armory of Buffalo, New York, was completely destroyed by fire on the evening of May 6, 1931, largely because of the difficulty of getting at the seat of the fire at the start. At 9:50 P.M., while members of the American Legion were drilling in the Armory, smoke was

observed coming up from the basement through a crack in the floor, and the fire alarm was immediately given. The fire department could not enter the basement on account of the smoke, and used cellar-pipes through holes chopped in the floor. These appliances proved ineffective because of the tremendous area of the building, which was 410 ft. long and 325 ft. wide. The second, third, and fourth alarms were sounded, bringing 36 engine companies. In spite of this large force, the fire spread to the roof, which collapsed at midnight sending up a shower of sparks and brands, which were carried by the wind and started more than 75 other fires on wooden shingle roofs. These were extinguished by firemen detailed from the main fire, assisted by householders and citizens.

The Buffalo Water Department estimates that the maximum rate of water consumption used at the Armory fire was 6 550 g.p.m. for three hours, and that in addition, at the other simultaneous fires within a mile of the Armory, 2 660 g.p.m. were used for a period of 1½ hours, or a total of 9 210 g.p.m. equal to a rate of 13.2 m.g.d.

Another large fire in Buffalo occurred on November 6, 1928, during which a number of large, old buildings were involved, with a loss estimated at $500 000. The quantity of water used in fighting this fire is as follows:

City mains	13 500 g.p.m. or 19.4 m.g.d.
High-pressure system	6 000 g.p.m. or 8.6 m.g.d.
Fire tugs	4 000 g.p.m. or 5.8 m.g.d.
Total	23 500 g.p.m. or 33.8 m.g.d.

Nashua, N.H. The disastrous fire in Nashua, N. H. last year, is another illustration of what may happen when water cannot reach the fire at the start. On Sunday afternoon, May 4, 1930, fire started in an old wooden railroad bridge covered on the top and sides by wood sheathing. The fire department soon had four or five strong streams playing on the bridge, but they were ineffective because they could not reach the seat of the fire which was inside the covered structure. Sparks and brands from the light sheathing were carried by the wind, igniting buildings to leeward, many of which had shingled roofs. The entire fire department could not cope with the rapidly spreading fire which burned over an area 1⅛ miles long and ⅛ mile wide containing two factories, several lumber yards, and numerous dwellings. The first call for help was sent to outside towns within one-half hour. Nineteen cities and towns sent twenty-six pumpers and three hundred firemen. (See Fig. 5.)

The maximum draft during the fire was about 7 500 g.p.m. or 10.8 m.g.d. About 5 000 000 gal. of water in excess of normal consumption are estimated to have been used during the fire. A 6-m.g.d. pump was operating when the fire started, and for the first three hours this pump and the 4 000-000-gal. reservoir supplied the water needed. Then an 8-m.g.d. reserve pump was started. The pumps supplied most of the water, for the reservoir

lost less than 1 000 000 gal. (See Fig. 6.) The conflagration placed an extremely heavy demand on the distribution system. Added to the fire draft was the wastage from broken service connections and some abandoned hose lines. Larger mains than the 8-, 6-, and 4-in. gridiron within the fire zone might have saved some buildings along the edge of the burned area, but probably would not have much reduced the rapid spread of the con-

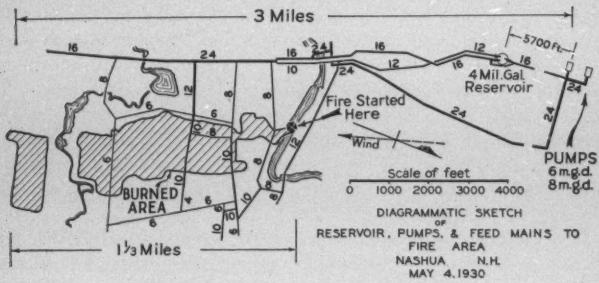

FIG. 5.— NASHUA CONFLAGRATION.
Extent of fire; water mains, pumps, and reservoir.

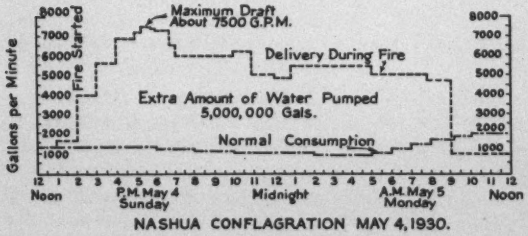

FIG. 6.— CHART OF WATER CONSUMPTION.
Fire occurred on Sunday when normal consumption was low.

flagration. The abolition of shingled roofs is the real solution in preventing sweeping fires of this kind.

Norfolk, Va. A recent fire which threatened to reach conflagration proportions occurred on June 7, 1931 in the waterfront and wholesale district of Norfolk, Virginia, calling out all the available fire department equipment and personnel in the city. Twelve pieces of apparatus were sent from surrounding towns, as well as five hundred men from the Norfolk Navy Yard. Four pier sheds and approximately sixty other buildings were either destroyed or badly damaged, involving an estimated property loss of $1 250 000.

From an official estimate, about 3 600 000 gal. of water above normal consumption were supplied by the public mains for this fire, in addition to the water delivered by the fire boat and various harbor tugs. (See Fig. 7.) The fire chief reported no shortage of water during the fire.

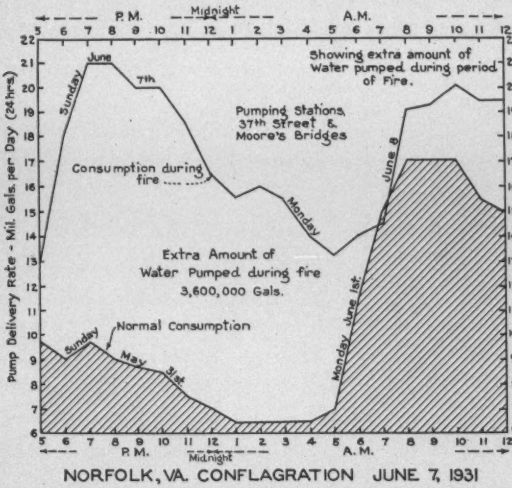

FIG. 7.— CHART OF WATER CONSUMPTION.

Note that fire occurred on Sunday when normal consumption was low. Had the fire occurred a day later, the peak of the fire-draft would have been added to the heavy Monday morning consumption.

GENERAL EXPERIENCE AND REQUIREMENTS.

The generally accepted standard for the total quantity of water which should be available for fire service in the average city is that in the Standard Grading Schedule of the National Board of Fire Underwriters. Typical quantities according to this standard are as follows:

Population.	Required Maximum Fire Flow g.p.m.	Population.	Required Maximum Fire Flow g.p.m.
10 000	3 000	60 000	7 000
13 000	3 500	80 000	8 000
17 000	4 000	100 000	9 000
22 000	4 500	125 000	10 000
28 000	5 000	150 000	11 000
40 000	6 000	200 000	12 000

For cities of more than 200 000 population the fire flow should be 12 000 g.p.m. plus 2 000 to 8 000 g.p.m. additional for a second fire.

TABLE 1.— WATER CONSUMPTION DURING TYPICAL SWEEPING CITY FIRES AND CONFLAGRATIONS.

Location. Date. Fire Loss.	Maximum Fire Flow. m.g.d.	Maximum N. B. F. U. Standard. m.g.d.	Peak Rate, Domestic & Fire. m.g.d.	Max. Daily Domestic Rate. m.g.d.	Total Pumping Capacity. m.g.d.	Extra Water Used. mil. gal.	Duration of Fire. hours	Remarks.
Norfolk, Va. June 7, 1931. $1 250 000	12	14.4	21*	14.2	61	3.6	6½	Fire on Sunday. Ample water.
Nashua, N. H. May 4, 1930. $2 500 000	9	7.2	10.8*	4.6	14 4 mil. gal. res.	5	9	Fire on Sunday. Pumps and reservoir ample. Mains overtaxed. Pressure exhausted in fire area.
Fall River, Mass. Feb. 2, 3, 1928. $2 550 000	26.2	14.4	31*	9.3	24 5.3 mil. gal. S. P's	20	12	Ample water. Maximum demand exceeded pump capacity. 2.5 mil. gal. from standpipes.
Nashville, Tenn. March 22, 1916. $1 500 000	6.5	14.4	17.5	17.3	47 mil. gal. res.	..	4¾	Ample water generally except at higher elevations. 50-m.g.d. pump limited to 20-m.g.d. by old force main to reservoir.
Salem, Mass. June 25, 26, 1914. $8 000 000	22	8.6	26	4.1 Av'ge high month	10 20 mil. gal. res.	16	13	Emergency connections to three towns used. Cement-lined mains burst. Water inadequate.
Chelsea, Mass. April 12, 1908. $12 000 000	21	7.2	23	6 Av'ge high month	Large res. of Metropolitan System	29	7½	Fire on Sunday. Good water supply and gridiron. Pressures became low due to heavy draft and broken pipes.

*Additional details in text.

Quoting from the 1925 Manual of Water Works Practice of the American Water Works Association:*

It is quite common practice to provide for delivery of the maximum fire flow coincident with ordinary draft at the average rate of the maximum day — which in general will approximate the peak hour rate of the average day. Freeman suggested the absolute maximum domestic rate as that which "should always be kept in view as the basis over and above which the fire supply is to be secured"; while it is the view of Nicholas S. Hill, Jr. (1915

TABLE 2.— WATER CONSUMPTION DURING SEVERE LOCALIZED FIRES.

Location. Occupancy.	Date and Fire Loss.	Maximum Rate of Consumption. (Fire only.)			Duration of Fire.	Extra Water Used.
			g.p.m.	m.g.d.	Hours	Mil. gal.
Baltimore Post. Baltimore, Md. Newspaper Office.	Jan. 1, 1931 $156 000	City Mains	9 000	12.9	2	1.6
		High-Pressure System	9 000	12.9		
		Total	18 000	25.8		
Buffalo, N.Y. Group of old buildings.	Nov. 6, 1928 $500 000	City Mains	13 500	19.4		
		High pressure System	6 000	8.6		
		Fire tugs	4 000	5.8		
		Total	23 500	33.8		
106th Field Art. Armory, Buffalo, N. Y.	May 6, 1931 $7 000 000	City mains	9 200	13.2		
C. B. & Q. R. R. Chicago, Ill. Office Bldg. and Adjoining Prop.	Mar. 15, 1922 $5 000 000		16 600	23.9	1½	16.8
Union Switch & Sig. Co. Swissvale, Pa. Machine Shop.	Feb. 10, 1917 $2 250 000	City mains	4 750	6.8	6	2.1
		Fire pumps	2 000	2.9		
		Pumpers	500			
		Total	7 250	10.4		
Baldwin Loco. Wks. Philadelphia, Pa. Machine Shop.	Jan. 29, 1907 $150 000	City mains	3 850	5.5	1	1.1
		Fire pumps	2 750	4.0		
		Total	6 600	9.5		
Cocheco Mill, Dover, N. H. Cotton Mill.	Jan. 26, 1907 $480 000	City mains	3 000	4.3	10½	8.2
		Fire pumps	2 500	3.6		
		Pumpers	700			
		Total	6 200	8.9		

Amer. Water Works Assn., p. 142) that "it will not usually be necessary to provide carrying capacity for a quantity greater than the average daily demand during the maximum one week of the period considered, in addition to the fire service requirements."

Table 1 of this paper shows the actual peak rate of water consumption and the maximum fire flow during six typical sweeping fires. It also shows

*Page 300.

for comparison the recommended maximum rate according to the standard of the National Board of Fire Underwriters, the maximum daily domestic rate, and the total pumping or reservoir capacity. The fire flow which should be available for a serious local fire according to the Grading Schedule of the National Board of Fire Underwriters is from 3 000 to 6 000 g.p.m.

Quoting again from the 1925 Manual of Water Works Practice of the American Water Works Association:*

The duration of maximum fire flow for which provision should be made is suggested by Freeman as six hours, and such basis of design is quite common in the smaller cities and towns where dependence for fire supply is placed in part upon storage in standpipes or elevated tanks. The Underwriters recommend five hours fire flow for towns of less than 2 500 population, and ten hours for larger communities.

TABLE 3.— REPRESENTATIVE HIGH-PRESSURE FIRE-SYSTEMS.

City.	Number of Pumps.	Maximum Pressure.	Capacity.	
			g.p.m.	m.g.d.
Atlantic City	9	150	12 000	17.3
Baltimore	3	210	12 700	18.3
Boston	4	200	19 000	27.4
		300	12 300	17.7
Buffalo	3	200	9 000	12.9
Cleveland	4	270	10 000	14.4
Detroit	6	300	15 000	21.6
Manhattan, N. Y.	12	300	36 000*	51.9
Brooklyn, N. Y.	8	300	26 400	38.0
Coney Island (Now)	3	150	4 500	6.5
(Under Construction)	5	225	13 500	19.5
Philadelphia	20	300	21 450	30.9
San Francisco	8	300	24 000	34.6
Winnipeg, Man.	3	300	10 800	15.5

*Heaviest draft was in 1909 for five fires at once. Seven pumps delivered 34 000 g.p.m. at 225 lb. per. sq. in. average pressure.

It will be noted from examples of serious local fires given in Table 2 of this paper that the above recommended rates of flow from the public mains were exceeded in four of the fires, and that the recommended duration of fire flow was exceeded at the Cocheco Mill fire. It is not at all unusual today to use 20 to 30 hose streams (5 000 to 7 500 g.p.m.) to fight 3- and 4-alarm fires.

*Page 301.

High Pressure Fire Systems.

To supplement the regular municipal water systems during emergencies and furnish auxiliary water supplies of large volume, high-pressure fire systems are installed in the high-value districts of many large cities and special fire pumps are provided in large industrial plants. The capacities of representative high-pressure fire systems and private fire systems are given in Tables 3 and 4.

Fig. 8.— Drowning a Fire.
Seventy-five tons of water per minute at Baltimore *Post* fire, January 1, 1931.

The value of a high-pressure system is well illustrated by the fire-fighting methods employed when the Baltimore "Post" Building burned last January. The fire trapped eight men in the upper floors. The first work was naturally that of rescue, and seven men were saved by ladders; one man fell from a fourth-story window and was killed. Then close-range, inside fire fighting was followed until there was danger that the floors might collapse. By that time flames from the windows were endangering nearby buildings and it was decided to drown the fire with all available equipment. Pumpers supplied twelve hose lines from the regular hydrants, and the high-pressure system supplied thirty-four lines, some feeding wagon guns and water towers. The maximum rate of delivery to fight the fire and protect surrounding property exceeded 18 000 g.p.m. (See Fig. 8.) It was estimated that 1 600 000 gallons of water were used in the first two hours.

TABLE 4.— TYPICAL PRIVATE FIRE-SYSTEMS FOR INDUSTRIAL PROPERTIES.

Location.	Number of Pumps.	Maximum Pressure. lb. per sq. in.	Capacity. g.p.m.	Capacity. m.g.d.
Lowell, Mass. Locks & Canals System Supplies 9 Plants	9	80	18 500	26.6
	Also 4 000 g.p.m. from 2 mil. gal. reservoir at 60 lb. per sq. in.			
Lawrence, Mass. Supplies 8 Plants	23	100	27 000	38.9
New Bedford, Mass. Supplies 4 Plants	12	100	14 000	20.2
Moline, Ill. Supplies 9 Plants	10	100	10 000	14.4
Gatineau, P. Q. One Paper Mill	4	135	10 000	14.4
Three Rivers, P. Q. One Paper Mill	4	100	8 000	11.5

SUMMARY.

Many other examples could be given to demonstrate what large demands may be made suddenly on public water systems in order to control serious fires, but enough have been cited to illustrate the general principles that apply to the study of water consumption during fires. These may be briefly summarized as follows:

1. Most fires are extinguished promptly by hand equipment, by one or two hose streams, or by a few sprinklers. Therefore, the amount of water used is ordinarily small, but will be greatly increased if there is appreciable delay in applying the water after the outbreak of the fire, if the rate of application is not sufficient at the start, and if the water is not applied directly at the seat of the fire.

2. The peak load on public water systems for large fires is greater today than formerly because the mobility and speed of modern automobile fire apparatus enable large pumping capacities to be quickly concentrated in any city where needed.

3. Although the amount of water used annually for fire fighting in the average city is less than 1 per cent. of the total amount pumped, yet when a fire obtains a good start, the maximum rate of water consumption needed to control the fire and supply all other demands simultaneously may exceed the capacity of the regular water system. (See Tables 1 and 2 and National Board of Fire Underwriters Standards.)

4. This possible sudden large demand is the reason why supplementary water supplies of large capacities are provided in the form of special high-pressure fire systems for municipalities, and in the form of private fire pumps for individual properties of considerable value or hazard. (See Tables 3 and 4.)

DISCUSSION.

J. WALTER ACKERMANN.* It was my privilege to receive a copy of Mr. Mowry's paper for discussion, but it was a greater privilege, about twenty years ago, to work with Mr. Mowry on fire-protection apparatus. I know that whatever he says may be depended upon with the utmost confidence that it is a fact; I found that he was most exacting in his demands for proper fire protection and proper equipment to procure it.

Mr. Mowry has studied intimately the consumption of water at large conflagrations; he knows the subject in all of its ramifications and understands the water-works problems connected with it. Purely from the water-works point of view, rate of consumption is but one phase of water supply because, above all other things, the superintendent must provide a supply safe for human consumption. So far as fire protection is concerned, he deals only with discharge and pressure at any point in the distribution system.

For the past decade it has been necessary for me to study both fire protection and domestic supply as one of the many items in the complete governmental function of a city. I realize that there may be a question as to domestic water supply being a governmental function. The supply of water for the extinguishment of fires, however, comes under that classification without any doubt, and is so regarded by the income-tax collector. From the standpoint of aligning fire protection with police protection and other governmental functions for the protection of persons and property, fire protection, to my mind, has never been properly appreciated, classified, or paid for in proportion to the benefits received.

I speak principally of municipal water departments, because private ones see to it that fire protection is paid for on some equitable basis, as determined by the courts or public service commissions that have jurisdiction to fix or modify rates. In general, however, municipalities do not make scientific allowances for the part the water department plays in fire protection. They place in the budget an item for the expense of fire-department personnel and equipment to be paid for by general taxation, but very rarely do they place an amount in the tax levy for the value of fire protection that the water department furnishes. They rely instead upon the rate payer to meet operating expenses, upkeep and, perhaps, payments of interest and principal on the water debt. I believe this is entirely wrong in procedure. All should bear their just share of cost and expense to maintain the water department. For instance, the small rate payer should not have to pay for the fire protection furnished by the water department, through ample sized mains, for a large storage warehouse which does not use significant quantities of metered water but receives a very handsome reduction in fire-insurance rates because there is an

*City Manager, Fall River, Mass.

adequate water supply for fire protection. I have always advocated, unpopular though it may be to do so, that even in a municipally owned plant an amount should be placed in the tax levy for the water department in order to relieve the rate payer of paying for something from which he may have no benefit. The modern way of assessing this amount is on the basis of inch feet of main in the system plus a fixed charge for each hydrant.

In arguing before the Board of Aldermen that they should include something in their tax levy for fire protection and raise the balance by their rates, I have sometimes offered this illustration: In most cities street lighting is normally provided by private corporations. They make a certain charge for the street lighting. At the same time they receive a rate per kilowatt hour for domestic service corresponding to meter rates for water. Supposing the city said to the company: "We do not pay for fire protection, that is a sort of public benefit. Similarly you should not charge for street lights. If you don't make this charge we shall let you raise the rates high enough to give you more income from domestic consumers. Then we shall be able to tell the taxpayers that the street lighting is free." Fire protection is just as free as street lighting would be under those conditions. It is paid for somewhere.

I have been able in two cases to raise by taxation money for general fire protection in a municipally owned plant. That leads me to telling of two towns in the state of New York. One of them, a fair sized city, makes no charge for water. As a result there is no incentive to save water; consequently their per capita rate of consumption is high. The other town wanted to build a new city hall. Several attempts were made to get the citizens to vote an appropriation. They would not do so. The expedient was then adopted of raising the water rates high enough to cover the cost of the new building. Then property owners were told that the city hall would cost nothing.

Mr. Mowry made mention of Fall River. When I went there in January, 1931, I found out to my satisfaction that there was not a foot of 4-in. main in that city, and that there were more lineal feet of 8-in. distribution pipes than of 6-in. This is a very unusual case; some people must have had good heads on them years ago when they built that system. At the present time there is one more standpipe and one more pump than at the time of the great fire so that if ever there is another fire I think the gap shown will be very much less.

Mr. Mowry spoke of Indianapolis but he did not tell you why all factories did not put in sprinklers. The reason is that the water company charges so much a year for them, which is a proper procedure within limits.

The general public thinks that fire hydrants, since they are the visible evidence of the fire-fighting equipment of the water department, are the only things the water department has to furnish. Fire hydrants, it is my belief, should be installed, maintained and operated by no one except

employees of the water department and the firemen at a time of fire. Because of present-day hazards to hydrants due to the automobile and the auto truck, it seems necessary to have all hydrant branches gated so that repairs can be made following accidents without shutting off main lines in the distribution system. While individual opinions may differ, I believe that compression-type hydrants should be used for the same reason, or some device that will prevent the hydrant from flowing when broken off at the grade line.

While the water department does no direct fire fighting, it is the water department that furnishes the water under suitable pressure, either for use of direct hydrant streams or pumpers. Adequate mains are required and either adequate reservoir reserve or pumping capacity to meet peak demands in case of large conflagrations. This makes necessary a capital outlay, varying with the size of the city from about 50 per cent. of the cost of the whole water-works plant of small cities to perhaps 10 per cent. for larger cities. Thus there is a distinct relationship between fire-fighting capacity and domestic supply.

JAMES W. GRAHAM.* I have been much interested in what Mr. Mowry has told us. One of the things he brought out which should be carefully borne in mind by water-works superintendents is the present-day method of fire fighting, whereby many pieces of fire apparatus may be rushed into a burning town. The days of small pipes, 4 and 6 inches in diameter, are gone forever. As has been said, it ought to be against the law to manufacture such pipes. I think that statement was made in Portland three years ago when the convention met there. A fire broke out the night before the convention: many pieces of fire-fighting apparatus were brought into the town from nearby cities inside of twenty minutes. The rate of consumption for that fire was between 8 000 and 10 000 g.p.m. if I remember correctly.

One of the things which the Maine Water Utility Association has brought about, and which we believe is going to be helpful, is what we term the uniform method of grading hydrants. If you will bear with me I shall give you what has been worked out. The hydrants have been divided into three classes, A, B, and C. Class A includes fire hydrants which have sufficient capacity to supply one or more pumpers with 1 000 g.p.m. or more at a residual pressure of not less than 10 lb. per sq. in. Class B includes fire hydrants which have sufficient capacity to supply pumpers with 500 to 1 000 g.p.m. at a residual pressure of 10 lb. per sq. in. Class C hydrants are of sufficient capacity to supply pumpers with 500 g.p.m. at a residual pressure of 10 lb. per sq. in.

Class A hydrants are designated by green colored tops or caps; Class B are orange; Class C are red. This should enable outside fire companies to know whether or not there will be sufficient water for them to connect to a hydrant when other hydrants on the line are already tapped.

*Treasurer and General Manager, Portland Water District.

Another matter that occurred to me in hearing Mr. Mowry's paper is the importance of the automatic sprinkler. I fully agree with Mr. Mowry that the automatic sprinkler gives perhaps the best means to fight fire. Cross-connection, however, must be regulated. In Maine we have established regulations that are satisfactory; they require the provision of double check valves and the making of a monthly inspection report to the State Department of Health.

I do not know who was the originator of the fire sprinkler. Whoever it was, he may have got his idea from a happening in Portland some forty years ago. The main supply for Portland comes from Sebago Lake. The original supply was through a 20-in. cement-lined wrought-iron pipe. This main, in one particular place, runs behind a set of buildings and within 6 or 8 ft. of a large barn. During a very severe thunderstorm lightning struck this barn and set it afire. The fire spread rapidly, the whole roof became involved, and fire burned through into the hay. The same bolt of lightning, however, went down into the ground and cracked the water main, so that about an 8-in. stream of water was thrown over the barn and put out the fire. The amazing part of the story is that the next day the owner of the barn came to the water department to collect damages for the wetting his hay had received.

EDWARD E. WILLIAMSON.* Recently there was a fire at one of the forts in Boston harbor. We despatched one of our fire boats, which worked about four hours on the fire and did a lot of good work. When the boat was leaving the island, a colonel in the United States Army came down to the captain of the boat and said: "My gracious, captain, that was a wonderful job your fellows did today; I had no idea that one of those boats carried so much water."

We have been trying to teach our men who are looking for promotion a few of the formulas of hydraulics. The Civil Service Commission today asks a considerable number of questions on the capacity of pumps and the flow formulas of nozzles. Figures are pretty hard things for the men to handle, particularly the type of men in the fire department. We have, therefore, established classes and take the men out in yards and show them the operation of pumps. We also take the men out and put the pump to draft and work it from a hydrant, so that they will be familiar with the actual flow of water. It is surprising to see how quickly men grasp from actual practice as against theory.

One of the principal troubles I have noticed in my experience in the fire department is dead ends. In fires in which we have lost considerable property, the cause has generally been the existence of dead ends. If the water system is laid out with mains large enough to maintain the flow and a positive pressure at all times, then the system is ideal and can take care of all the pumps that are hooked on to the hydrants.

Another thing that is essential in a water department is a connection

*Superintendent of Maintenance, Fire Department, Boston, Mass.

with the fire-alarm system, as is the case in Boston. When a multiple alarm comes in, the pumping station is immediately notified. The operators will then be prepared and will not be caught the way the operators at Fall River were. They did start the third pump at midnight, but that third pump should have been started at the beginning of the fire, when a general alarm was sounded; then the loss of water from the mains could have been counterbalanced by the standpipes.

From my study of conflagrations it does not make any odds how many fire companies are brought in to fight a fire that has reached the conflagration stage, as there is no checkmate until it has burned itself out. When Mr. Mowry states that the first bucket of water or the first dash of water is the important one, that is the keynote. We realize very forcefully that once the fire reaches a conflagration point, all the fire departments we have and all of our apparatus are of no avail.

In addition to the amount of water that is used at fires, there is always the amount of water that is wasted at a fire. When a building has burned down, the supply pipe melts off, and the water goes into the cellar. That diminishes the pressure and thus hampers the firemen, for after the fire reaches a certain point the water is going into the cellars and pressure is lost.

Whenever a high-pressure hydrant is used in Boston we report it immediately to headquarters after the fire and send in a written report the following morning. A written report is made of the number of hydrants used at any fire, so that the water department can coöperate and inspect those hydrants at its earliest convenience the next day, to see that everything is in working order.

We have in Boston a considerable number of Lowry hydrants. This to my mind is an advantage to the firemen, because several pumpers can be massed around the Lowry hydrant, which is directly over the main and gives free flow of water to the pumper. Each individual pumper has to carry a Lowry chuck, which screws into the main. Four engines can get around one of these hydrants, whereas on a sidewalk hydrant or a post hydrant, two or three is the most.

On several occasions at the beginning of a fire the motor pumps coming in have hooked two or three 1 000-g.p.m. pumps onto a hydrant which was only built to supply perhaps 1 000 or 1 500 g.p.m. with the result that the first pumper in was all right but the other pumps could not get water enough. To avoid the occurrence we have issued a general order to the department that on certain hydrants, and with certain of our large pumps, only one pumper may be connected to a hydrant, or two 750-g.p.m. pumpers. Capacities should be figured by the superintendent of the water department and the chief of the fire department.

In connection with the purchase of a new fire boat for Boston we looked into the advisability of using Diesel engines, but for various reasons did not accept them. We also looked into the use of gasoline-drive, but

did not like to think of putting gasoline into a fire boat and having it at the scene of a fire. So that we stuck to steam. We found that for $350 000 the authorized expenditure, we could throw more water and get a more powerful boat with steam than with a Diesel-electric job, and we could keep away from starting difficulties, high maintenance cost and a multiplicity of working parts.

One of our old steam fire-boats has been in service thirty-five years, and it has never once missed responding to a fire alarm. The experience which I had with Diesel engines during the war was that many a time we could not start an engine within ten or fifteen minutes, and it took at least an hour or so to warm it up. Our steam fire boat is always warmed up and ready to get underway. The cost of the fuel that we propose to use on this boat furthermore will be less than the fixed charges on the additional cost for a Diesel-electric motor of the same capacity.

We also have to consider the factor of personnel. We are under civil service in Boston and our present engineers are marine steam engineers. If we adopted another means of propulsion, it would mean getting new men, or taking a long while to train our present men for that purpose.

Our new boat is to be about 125 ft. long. It has two oil-burning boilers with a steam capacity of 50 000 lb. per hour. The boat has fore and aft compound engines which turn at about 150 r.p.m. This will give the boat a guaranteed speed of 12 knots, equivalent to about 14 miles per hour. The pumps are two-stage, centrifugals driven by steam turbines. Each pump has a capacity of 2 500 g.p.m. at a pressure of 150 lb. per sq. in. or 1 100 g.p.m. at 300 lb. per sq. in. The boat is steered by steam and has radio equipment. It has all the necessary auxiliary pumps like bilge pumps, air pumps, circulating pumps, boiler-feed pumps. The boat is equipped with a complete deep-sea diving outfit, wrecking booms, gas masks, oxy-acetelene cutting outfit and foam and carbon dioxide tanks for fighting gasoline or oil fires.

George A. King.* Taunton's Holly System has been in operation for fifty-five years. There are no standpipes or distributing reservoirs. The pumps have run for fifty-five years and there has been no shutdown for breaks in the system. The pumping station is connected with the fire-alarm system of the city, and all alarms are registered. Immediately on an alarm coming in, the pressure is raised to 100 lb. per. sq. in. at the station gage. That gage is at El. 20; the highest point within the city limits is at El. 90. On certain boxes being sounded, the pressure is increased from 5 to 10 lb. per sq. in. more, according to needs. In two minutes we can raise the pressure from 70 lb. per. sq. in., which is normal, to 100 lb. per sq. in. We figure that we can get the pressure up before the fire department can reach the hydrant, and we are ready to give the necessary pressure at all times.

Since the installation of the system, the manner of handling fires

*Superintendent of Water Works, Taunton, Mass.

has changed. More pressure is demanded today. In this connection one of our councilmen asked the fire chief who had requested the purchase of a pumper why he didn't have hose wagons as he used to. I was summoned and my answer to the question was that more pressure was required today, and we could not give the high pressure demanded. Our system has never failed to give, at any fire, all it was designed to give. At two fires the full capacity of the supply main has been reached. Depending on location, we can give as high as 25 or 30 streams.

MR. ACKERMANN. I had the misfortune to operate a Holly system for nearly twenty years, although it was a little bit different, I think, from Mr. King's. The original source of water at Auburn, N. Y. was a stream from which water was taken by a Holly Gaskill pump. The man who set up the system ran it fifty-two years, and it is still running. When the stream became polluted the intake was shifted to a lake $1\frac{1}{4}$ miles away. A siphon line ran to the lake over the undulations of the ground. As a siphon, the pressure was on the outside rather than the inside. When the capacity of the line as a siphon was exceeded a pump was placed near the intake end to force water through the line. The pressure was thus transferred to the inside, and as nearly as I could find out, the pipe became stressed to the breaking point; it did break several times between the two pumping stations. If either station stopped the whole works stopped. Fortunately this never happened during a fire. The supply was off only twice for twenty minutes in twenty years. That is a fair record; but every time there was a fire alarm I was on pins and needles, expecting to hear of a break.

CHARLES W. SHERMAN.* There are one or two matters suggested in part by what Mr. Graham said, to which I think this Association might give a little more attention, not only at this meeting but perhaps at some future meetings.

I refer particularly to the mention of what the Maine Water Utilities Association has done in the way of standardizing hydrants and indicating their capacities by distinctive colors. I don't know whether it is possible for us, covering a large area and including a number of water-works systems which are larger in size than any in Maine, to work out a similar system of standards which would not be too complicated.

Of course such information as we have from Mr. Mowry is of the greatest importance in designing works, either for original supply or for reënforcement, to meet the greater demands that may come. Many times, however, water-works men are faced with the question, not so much of increasing the capacity of the works, but of adjusting what they have to use to the best advantage; not only, of course, for domestic service but for fire service. The marking of hydrants in some such way as to indicate to the firemen what they may expect from them, seems to me is a matter of very great significance. The immediate cost would be only

*Of Metcalf and Eddy, Consulting Engineers, Boston.

that of a few gallons of paint and a few days' time of a man to do a little painting, after the original determination of what the hydrants are good for. In some cases it may not be necessary to go even as far as that.

I have had occasion in the last few years to study water-distribution systems in several towns of moderate and small size and to recommend programs of improvements that would not call for very much money in any one year, spreading the work over a period of years. In many of those systems there was still remaining some 4-in. pipe, and even where the smallest size of main was 6 in. there were quite a number of hydrants with 4-in. branches. In every such case, at least in the more recent studies, I have recommended that at the very least they indicate by some distinctive color scheme the hydrants in the system which were fed by 4-in. branches. If the hydrants were painted black, I recommend a brilliant red band around them, so that the firemen might know they were the weakest in the system and avoid them. So far as I know, that recommendation has never been adopted by anybody to whom I made it, but I still think it is a good one.

I also think the fact of whether or not the hydrant has a shut-off valve on the branch is one that might be indicated, perhaps by a less conspicuous mark, but one by which at least the water-works superintendent could tell without having to refer to his files whether there was a gate or whether he had to shut off the line if there was a break.

I have no concrete suggestion to make but I do feel that we of the New England Water Works Association have got some valuable suggestions from our friends in Maine, and we can give them further study.

STEPHEN M. TAYLOR.* I agree with Mr. Sherman, that the idea is well worth serious consideration, or perhaps having a committee to give more consideration to it. If some standard marking could be devised whereby the firemen from one city going into another would find the same markings on the hydrants, showing their relative capacity, it would be of great advantage in a conflagration.

MR. MOWRY. It is extremely important that markings be uniform, because when pumpers from a great many communities assemble in one city they ought to know the symbols well enough so that they will all be working on the same plan. It is important that the Association appoint a committee to work up something which can be uniform.

MR. KING. I should like to point out that there still remains a diversity of sizes of suction hose and suction-hose connections. I would suggest that it would be well for the same committee to take up those matters also.

MR. TAYLOR. We have not yet discussed the financial side of this question, and I think that is well worth considering. You all know that it does increase the cost of our systems considerably to provide for fire flow. I do not believe a great many of us get any consideration for hydrant

*Superintendent of Water Works, New Bedford, Mass.

protection in our rates from the city. I was just looking over the list of the Metropolitan District, and very few of the cities apparently get any hydrant rental. I think the same condition would carry through the whole of the New England territory. I do not know that it is any use to express our opinions on that subject, and perhaps there would be a difference of opinion. It is my opinion, however, that we should collect something not only for the public hydrants but for the private water-supplies. Our practice in New Bedford on private water-supplies is that the owner of the property installs and maintains the private fire system. The city is bound to furnish fire protection to that property through public hydrants. If the owners of the property see fit to provide their own hydrant or sprinkler system, no charge is made over and above the cost of their installation and maintenance, including quarterly inspection of the double check valves. In some places they charge either according to the size of the connection or number of heads or number of hydrants, or on some other basis. That question might be worth discussing.

JOHN S. CALDWELL.* I am fully in agreement with everything that Mr. Mowry has said relative to the peak loads which water departments are called upon to meet at the time of conflagration. I am much interested in the scheme which the Maine Water Utilities have evidently embarked on of designating hydrants according to their ability to furnish certain quantities of water. Mr. Mowry is correct that there should be uniformity in the designation, and it would not be a very difficult matter to determine what each of those hydrants would be capable of delivering.

I think most of us realize that Lowry hydrants are going out of existence. They are not being used to the extent that they used to be.

DAVID E. MOULTON.† Lest silence might give consent and my friend Mowry say that I remained silent under the intimation that it was not proper to make a charge for private fire service, I must raise my voice. It is a fact that the party who has a private fire service is securing from the water department an additional service over that which his neighbors are having and for which they are both paying in their tax levy. We are all apt to consider the imposition of charges for furnishing water as though we were *selling a commodity rather than furnishing a service.* It does not make any difference whether we furnish the water or not, if we have been to the expense of standing ready to furnish it, and every argument that is put forward for having free private fire-protection would be an equally good argument that the Boston and Maine Railroad should not charge me anything to go back to Portland. They are going to run their train anyway, and it doesn't cost any more to take me down than it would if they did not take me.

CALEB M. SAVILLE.‡ I am heartily in accord with what Mr. Mowry

*New England Insurance Exchange, Boston, Mass.
†Attorney, Portland Water District, Portland, Me.
‡Chief Engineer, Water Bureau, Hartford, Conn.

has said, and I am so much in favor of it that I was going to ask him later if I could get him to come to Hartford and say this same thing before one of the organizations down there, for I am sure that the conditions stated by him are for the most part unknown to most property owners.

Now in regard to payment. It seems to me that there are good arguments on each side of this discussion. I feel, however, that care must be taken to distinguish between taxpayers and water consumers. The water department should have enough money to pay its running expenses, and above all should have its own money to use. The taxpayers, as a whole, should pay their share, and it is seldom that they do pay their share. In regard to the manufacturers and the mill owners, there is a plausible argument for saying that they should pay for private fire-protection service, as their insurance rates decrease tremendously when they install sprinklers in their buildings. There is also something to say on the other side of that argument. If one of the big factories burns down at this time, with all the depression that there is, the owners of that factory very likely would put the insurance money in their pockets and say, "We will wait a while," and then you are going to have a lot of people on your hands to take care of if they do not move away; so, the protection of mill property is an insurance for the town, and as such may appear in the taxes if it can be adjusted equitably.

MR. MOWRY. I agree heartily with Mr. Saville that the taxpayer should pay, but I think that he should pay in proportion to the service that he receives from the water department and to the demands which he makes upon it. The thing which has always seemed unfair to me is that a man will operate, we will say, a big planing mill or lumber yard, with no private fire protection whatever, which may in time of fire make a demand upon the water system greater than anything else in the city. The cost of providing street mains and hydrants needed for the lumber yard is paid for out of general taxation, and a water department may have to lay large sized mains around his plant. Yet another owner, who has a much safer property of the same value, and also has private fire-protective equipment, pays exactly the same amount in taxes as the man who is going to make this great demand upon the water and fire departments. That seems unjust to me. So if this general cost of the water system is going to be distributed by taxation, why not base it upon the probable demands that are going to be made upon the water system rather than penalize the man who wishes to extend, so to speak, the public fire-protection system into his plant? Sprinkler systems, we all agree, make less demand upon the public water-system and the fire department than the use of hose streams for fire fighting.

MR. SAVILLE. We will not all agree with that.

MR. MOWRY. Well, in the majority of cases; that is, for the ordinary fire. The man who has a tall building and installs a standpipe has introduced something which is a distinct aid to the fire department in getting

the hose lines upstairs. That is, he has extended the public water system up into the building. I do not think he should be penalized for doing that. If he wants to put a loop of pipe in his yard and put in hydrants which are a help to the fire department, I do not think he should be penalized for that either. That is a distinct assistance. I think if there is to be some charge, it should be on an equitable basis, and it should be lower to the man who has provided fire-protective equipment.

MALCOLM PIRNIE.* Let me ask whether or not sprinklers require a pressure on the top floor of the building beyond that associated with a certain water use on the street, where we all know that the pressure can be pulled down in the hydrants with a pumper to practically zero at the street level and still yield sufficient water. Isn't there an extra demand on the part of the sprinkler system before it receives a first-class rating?

MR. MOWRY. It is true that sprinklers are of no use without pressure, it also is true that it is unjust to make the same charge for a 4-in. and 6-in. connection from a supply that cannot deliver water to the top sprinklers as for another supply that can deliver ample water. Naturally if there is a charge it should be varied according to the value of the service; not just because it is a 6-in. pipe, but rather on what it will deliver.

W. C. HAWLEY.† I want to agree with everything that Mr. Moulton said, and to agree with Mr. Mowry to a certain extent. Mr. Mowry mentioned one case where the fire-protection line had been shut off for repairs and a fire broke out. At a fire at Swissvale, Pa., the water was off when a fire broke out. They turned the water on shortly thereafter, but during that fire for several hours, about 30 000 g.p.m. went to waste. The firemen had to bring in eleven fire streams from outside the factory yard. Now, there was an extra load which was not figured on when the distribution system was designed. That sort of thing will have to be taken into consideration in fixing rates for private fire protection.

I have nothing to say as to how municipally owned plants shall fix their rates. I think they are not generally fixed on the basis of cost. As to private water companies, so far as I know, with the exception of a few decisions by the Wisconsin Commission in the early days, none of the commissions have had the intestinal fortitude to fix rates for public fire protection on the basis of actual cost. I know they have not done it in Pennsylvania.

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*Consulting Engineer, New York, N. Y.
†Chief Engineer, Pennsylvania Water Co., Wilkinsburg, Pa.

PROCEEDINGS.

December Meeting.

Hotel Brunswick, Boston, Mass.

Wednesday, December 9, 1931.

President George C. Brehm in the Chair.

Secretary Gifford announced the election by the Executive Committee of the following new member:

Winthrop C. Butts, Operator of Pumping Station and Filter Plant, Putnam, Connecticut.

The President. It is with sincere sympathy that I wish to call the attention of this Association to the recent death of one of our oldest members,—Mr. William H. Vaughn, Superintendent of the Water Department, Wellesley, Mass., a member since December 11, 1889, who died yesterday morning. I ask the members of the Association and our guests to rise and stand for a minute in silence in tribute to Mr. Vaughn.

(*Everybody rises and stands in silence.*)

The President presented as the topic of the meeting "Looking Backward," a symposium (see p. 66), in which the following members who joined the Association before 1890 took part:

A. W. F. Brown, Registrar and Superintendent of Water Works, Fitchburg, Mass.; a member since June 17, 1887.

John C. Chase, Treasurer, The Benjamin Chase Co., Derry, N. H.; a member since June 19, 1884.

Byron I. Cook, Inspector, Factory Mutual Fire Insurance Companies, Woonsocket, R. I.; a member since March 13, 1889.

Lewis M. Hastings, City Engineer, Cambridge, Mass.; a member since June 13, 1889.

Josiah S. Maxcy, Treasurer, Calais Water and Power Co., Gardiner, Me.; a member since December 14, 1887.

Dwight Porter, Professor (emeritus) of Sanitary Engineering, Massachusetts Institute of Technology; a member since March 13, 1889.

J. Clifton Whitney, formerly Water Commissioner, Newton, Mass.; a member since June 17, 1887.

The President. We also have a number of members who joined the Association prior to 1890 but who were unable to attend today for various reasons. I shall read their names:

Walter H. Richards, New London, Conn.; a member since October 11, 1882.

Carroll P. Bassett, President and Treasurer, Bassett Estates, Summit, N. J.; a member since June 13, 1889.

William F. Codd. Member of the Water Board, Nantucket, Mass.; a member since June 21, 1885.

Albert B. Drake, Civil Engineer, New Bedford, Mass.; a member since April 21, 1885.

Charles H. Eglee, Industrial Engineer, Brookline, Mass.; a member since June 13, 1889.

John R. Freeman, Consulting Engineer, Providence, R. I.; a member since December 12, 1888.

Harry C. Heermans, Hoquiam, Wash.; a member since June 16, 1886.

William P. Molis, Superintendent of Water Works, Muscatine, Ia.; a member since June 17, 1887.

William Wheeler, Consulting Engineer, Boston, Mass.; a member since December 11, 1889.

Secretary Gifford read communications* from Mr. George E. Watters, City Engineer, New London, Conn., with reference to Mr. Walter H. Richards; and from Messrs. Wm. F. Codd, C. H. Eglee, John R. Freeman, and William Molis.

Mr. John C. Chase. Mr. President, I think it is no more than fitting that we should recognize the absence of the senior member of the Association — Mr. Richards — by having the Secretary send to him in his absence our sympathy with him in his ill health. I make that as a motion.

(*The motion is duly seconded and unanimously carried.*)

A general discussion of the use of water in gas operated refrigerators was opened by David A. Heffernan, Superintendent Water Service, Milton, Massachusetts, and was participated in by Herbert C. Crowell, Howard M. King, James J. Fitzgerald, Henry T. Gidley, H. C. Mandell, Henry V. Macksey, Brenton W. Vaughan, E. F. Hughes, Frank J. Gifford, William F. Sullivan, James W. Graham, S. Alfred Benson, and David E. Moulton.

George R. Copeland of the Electrolux Company and George P. Langton of the Arlington Gas Company spoke on the subject from the points of view of their companies.

(*Adjourned.*)

*Editor's Note. Letters from Messrs. Harry C. Heermans and Albert B. Drake were read at the January, 1932, meeting.

JANUARY MEETING.

HOTEL BRUNSWICK, BOSTON, MASS.

Wednesday, January 13, 1932.

President George C. Brehm in the Chair.

Secretary Gifford announced the election to membership of the following:

Members: Walter Merrill Hatch, Superintendent, Whitman, Mass.; Thomas Haviland Stothart, Foreman, Weymouth, Mass.

Associate: Crane Co. (Ellis P. Abbott.)

The Secretary then read letters from the following members of long standing in the Association; Harry C. Heermans and Albert B. Drake.

Mr. Samuel E. Killam, Chairman of the Engineering Council of the Engineering Societies of Boston, spoke briefly on the work of these Societies on unemployment relief and on the licensing of engineers.

Mr. Robert Spurr Weston spoke about the proposed Water Works School to be conducted by the Association in coöperation with the staffs of the Departments of Sanitary Engineering of Harvard University and the Massachusetts Institute of Technology.

The first subject for discussion was "Experiences with the Operation of Smaller Water Works Systems." This was participated in by D. W. Foster, Superintendent, Wilmington Water Department, North Wilmington, Mass., William Naylor, Superintendent of Maynard Water Department, Maynard, Mass., C. A. Bingham, Town Manager, Norwood, Mass., B. L. Winslow, Town Manager, Stoughton, Mass., and David A. Heffernan, Superintendent of Water Service, Milton, Mass.

A paper on "Water Works in Cuba," was read by Mr. John F. Pierce, Civil Engineer, South Weymouth, Mass.

(*Adjourned.*)

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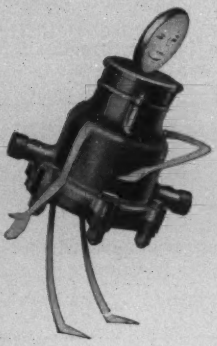

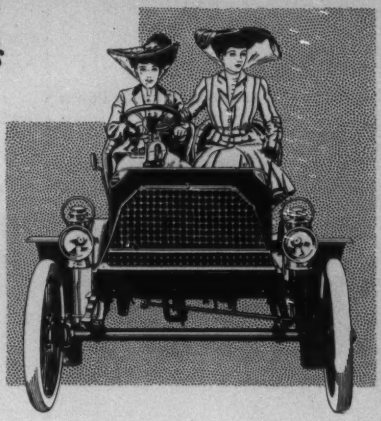

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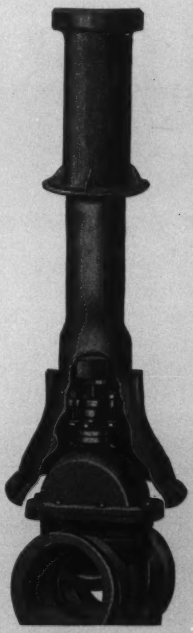

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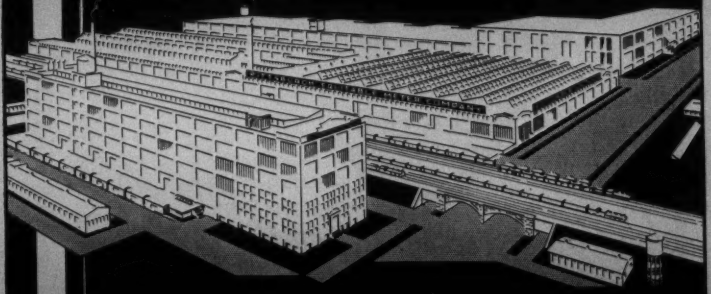

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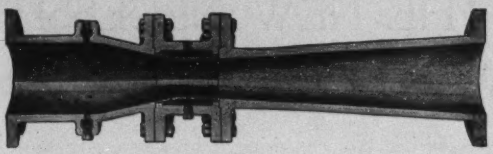

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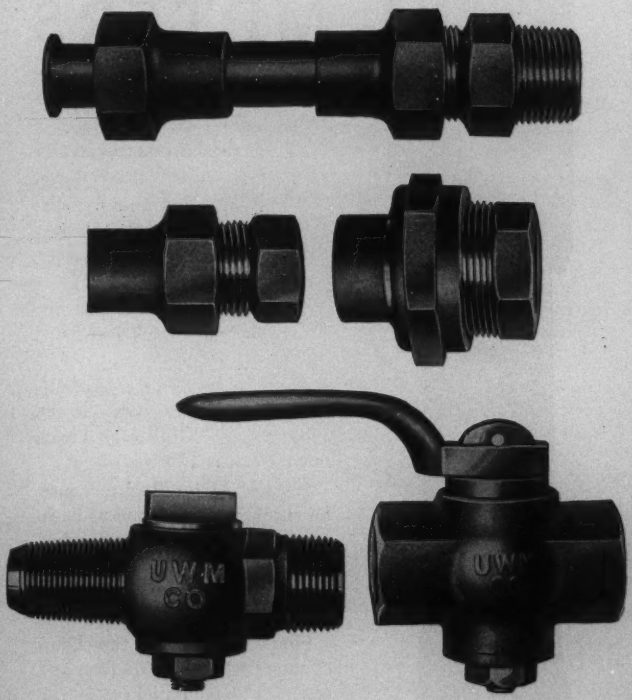


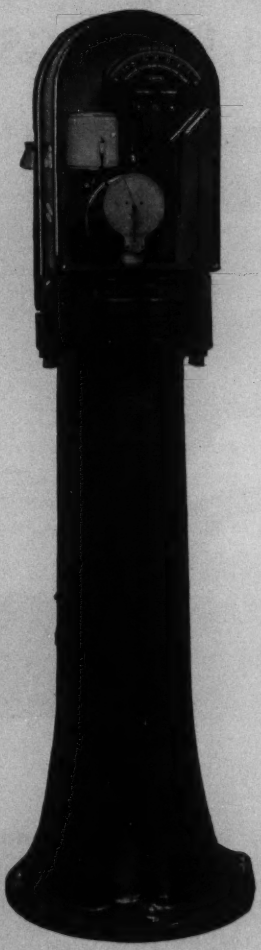
Heavier and stronger for maximum service. Ground and lapped to perfect bearing. Tested under 250 lbs. water pressure.

UNION WATER METER CO., Worcester, Mass.

INCORPORATED 1868

WATER METERS
CHRONOMETER VALVES

EASY TURNING STOPS
PRESSURE REGULATORS



SIMPLEX
VENTURI TYPE
METERS

Indicate the flow on a uniformly graduated dial.

Record the flow on a rectangular chart with uniform graduations.

Totalize the flow on a five-dial totalizer, so designed that the last figure can be read with accuracy on a much larger scale.

They may be furnished for floor stand, wall bracket or panel mounting.

May be used for pump discharge — gravity supply — in the Filter Plant — or Sewage Treatment Works.

Simplex Meter Registers may be checked at any time while in service by use of apparatus furnished as standard equipment — an exclusive feature of the Simplex Meter.

Simplex Meters are the choice of many who value quality and accuracy above initial cost.

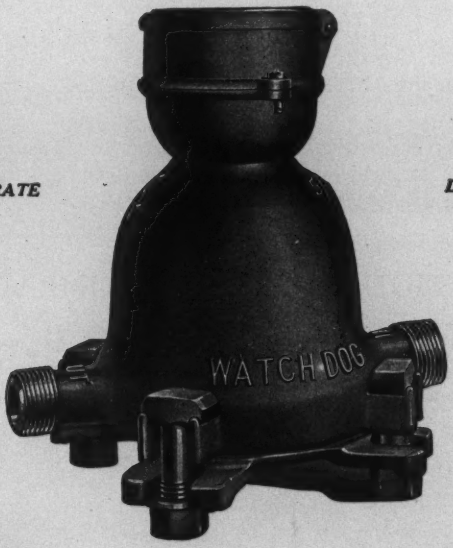
Write for data.

Simplex Valve and Meter Co.

6757 Upland St., Philadelphia, Pa.

"WATCH DOG" WATER METERS

ACCURATE *DURABLE*



DISC, CURRENT AND COMPOUND TYPES

Inquiries Solicited

GAMON METER COMPANY

NEWARK NEW JERSEY

METERS

The Kind You Want—As Many As You Want—When You Want Them

Six distinct types. All wanted sizes. Highest quality. All backed by a meter making experience of over sixty years. Remember the names:— **Empire, Nash, Crown, Gem, Empire-Compound and Premier.**

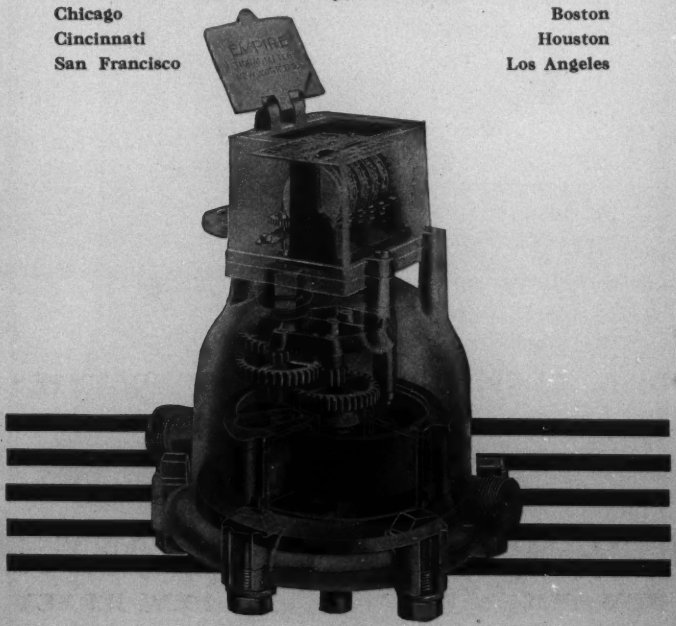
Especially remember the **Empire** (illustrated), the famous Oscillating Piston meter, which measures more accurately, is longer lived and lower in upkeep cost than any other.

Send postal for our meter literature.

NATIONAL METER COMPANY

299 Broadway, New York

Chicago **Boston**
Cincinnati **Houston**
San Francisco **Los Angeles**



Badger Sensitiveness Assures Accurate Registration on the Smallest Stream

Badger Model A-SOT equipped with breakable bottom plates which in the event of freezing give way with the expansion of ice and relieves the working parts of abnormal pressure.

Those little streams that trickle by carry away revenue — profit that must be safeguarded. This is the service in which the Badger-Disc Meter is a "natural."

Extreme disc sensitiveness — that's the reason — it catches the smallest stream—records it accurately.

And there are other "built-in" advantages — larger capacity — least absorption of pressure — unit assembly, fewer parts —all bronze housing.

Get the complete story presented in our bulletin No. 300. Your copy is ready, where shall we send it?

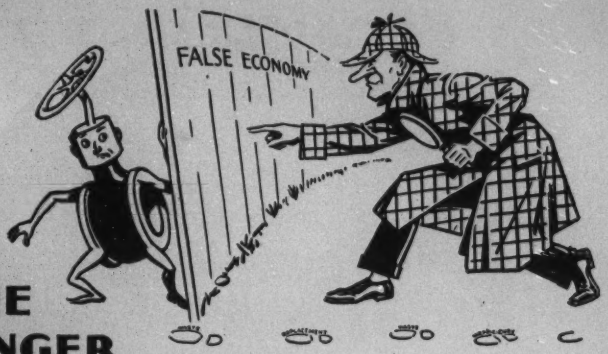
BADGER METER MANUFACTURING CO.

Milwaukee Wisconsin

Branches in

New York City — Waco, Texas
Cincinnati, Ohio — Savannah, Ga.
Chicago, Ill. — Seattle, Wash.
Los Angeles, Cal. — Philadelphia, Pa.
Kansas City, Mo.

BADGER Water METERS



THE FINGER POINTS

Today the finger of suspicion is pointing directly at the false economies of cheap buying. The hunt is on, to track down every factor that causes waste and extravagance. Cheap valves are notorious malefactors in increasing operating expense and cutting profits. Low first cost is rapidly overwhelmed by wasteful operation and costly replacement.

Join the forces of efficiency and ultimate economy by standardizing on Darling Gate Valves. Constructed on sound mechanical principles, with an exclusive feature that insures long and satisfactory service — parallel seats and revolving gate discs that seat in a different place each time the valve is closed — Darling Valves will soon demonstrate their superior operating possibilities. The complete record on Darling Valves is contained in an interesting catalog. Write for it.

DARLING VALVE & MFG. CO.

Williamsport, Pa.

NEW YORK OKLAHOMA CITY HOUSTON

DARLING

GATE VALVES

CITY OF CONCORD, N. H.

METCALF & EDDY, Engineers P. R. SANDERS, Superintendent

Using Morris Machine Works Pumps:—

Two motor centrifugal units, each 1000 G.P.M., 310 ft. head, 1750 R.P.M.

One gasoline engine driven unit 1000 G.P.M., 310 ft. head, 1200 R.P.M.

All units fed from sand tank on which a vacuum is automatically maintained which draws water from a number of driven wells.

This is a typical high grade station, of which we have built many.

STARKWEATHER & BROADHURST, INC.

BOSTON, MASSACHUSETTS

79 MILK STREET Tel. HANcock 4530

It Pays to Specify . . . .

"MINERALEAD"

For Jointing Bell and Spigot Water Mains

PERFECT JOINTS

Complete at one pouring

INGOT FORM

Impervious to moisture
Convenient to handle
Eliminates waste

New England Distributor
FRED A. HOUDLETTE & SON, INC.
40 Central Street
Boston, Mass.

The Atlas Mineral Products Co.
OF PENNSYLVANIA
Mertztown, Pennsylvania
Established 1892

Developed and manufactured by the originators of G-K Sewer Joint Compound

CLEAN PIPE LINES

having high coefficients deliver more water and give better fire protection than corroded mains.

High coefficients mean greater delivery in gravity mains and lower power costs in pumping mains.

GENERAL PIPE CLEANING COMPANY

Commercial Trust Bldg. Philadelphia, Pa.

F. A. MAZZUR CO., INC.

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WATER PUMPING INSTALLATIONS
SEWAGE PUMPING INSTALLATIONS
PUMPING STATIONS
POWER PLANT EQUIPMENT
SUCTION AND FORCE MAINS
TRANSMISSION LINES
SUBMERGED SUCTION LINES
DRIVEN WELL SYSTEMS

Emergency Work a Specialty

All Types of Pumps in Stock for Rental

141 MILK STREET Phone HANcock 4570 BOSTON, MASS.

NO BUMP TOO HARD

THE Smith O'Brien Hydrant never lets go its hold on the water at its main valve, no matter how hard it may be bumped.

That is because the pressure of the water itself, in the main, will automatically close the valve, even if it is only five pounds, no matter what damage may be done to the standpipe.

SMITH WATER WORKS SPECIALTIES & SUPPLIES

THE A.P.SMITH MFG.CO. *East Orange N.J*

THE METER BOX COVER WITH THE *HINGE EFFECT!*

A Real Boon to the METER READER

WHEN you buy meter box covers, consider the man who reads the meters and opens hundreds of meter boxes every day. The Ford Type X cover with the hinge effect, *saves time and effort with every meter reading.*

Notice the illustrations above and at the left. The lid may be leaned back as though it were hinged. *No mud, snow or leaves are dragged into the meter box when the lid is replaced. Write for prices.*

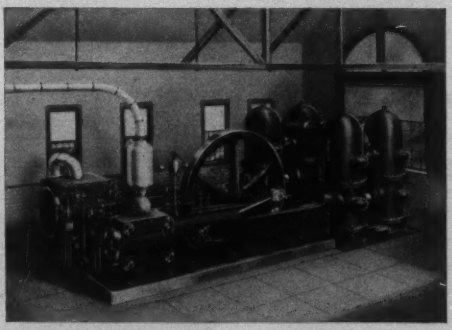
The FORD METER BOX CO.
WABASH, INDIANA
WATER METER TESTING AND SETTING EQUIPMENT

MURRAY IRON WORKS CO.

(INCORPORATED 1870)

BURLINGTON, IOWA, U. S. A.

Builders of High Duty Pumping Engines

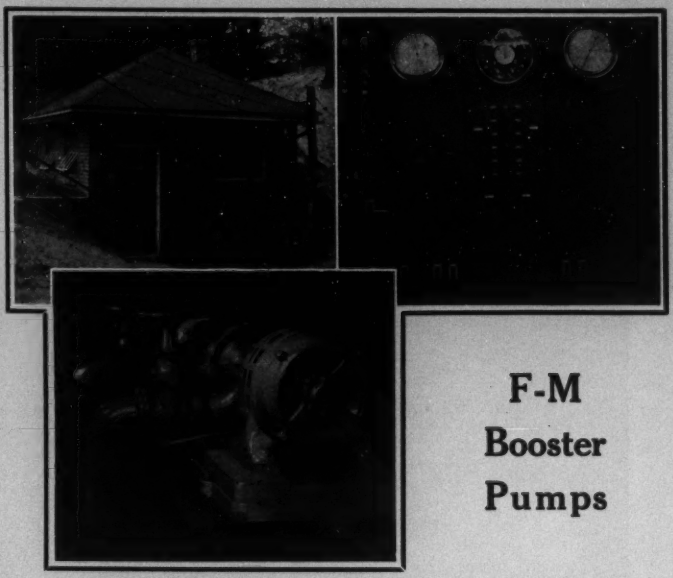


Murray High Duty Crank and Fly Wheel Pumping Engine, Opposed Type

STARKWEATHER & BROADHURST, INC.,
79 MILK STREET, BOSTON

will be glad to show you the superior design and excellent workmanship of the new 3 M. G. D. Murray Pump in the Arlington Pumping Station of the Metropolitan District Commission. Exceptional operating results are being obtained as shown by the official duty test which exceeded the guaranty by a substantial amount.

PLEASE SEND US YOUR SPECIFICATIONS AND CALLS FOR BIDS



F-M Booster Pumps

At SOUTH HADLEY, MASS.

Shown above are the exterior of the South Hadley Water Works Pumping Station, the two F-M Motor Driven Centrifugal Pumps installed in the station and the control equipment. The station is located at one extreme end of the town and takes water from a small reservoir under a positive head of approximately 12 or 15 feet and pumps it through the main section of the town to a standpipe at the other end. Both pumps and motors are of ball bearing design, which construction was selected because of the desirable feature of lubrication. The bearings require attention only once a year.

FAIRBANKS, MORSE & CO.

88 High Street, Boston

FAIRBANKS-MORSE

PUMPS · DIESEL ENGINES · MOTORS

DE LAVAL

Steam Turbine Driven Centrifugal Pumps with Condensing Equipment

Millis, Mass.

A SMALL highly efficient DE LAVAL turbine driven centrifugal waterworks pump complete with centrifugal injection pump and multi jet type condenser replacing obsolete reciprocating steam pump.

Capacity per day - - - - -	750,000 Gallons
Head - - - - - - - - - -	190 Feet
Steam Pressure - - - - -	80 lb. Gauge
Exhaust - - - - - - - - -	28″ Vacuum

Complete Installation by

TURBINE EQUIPMENT COMPANY

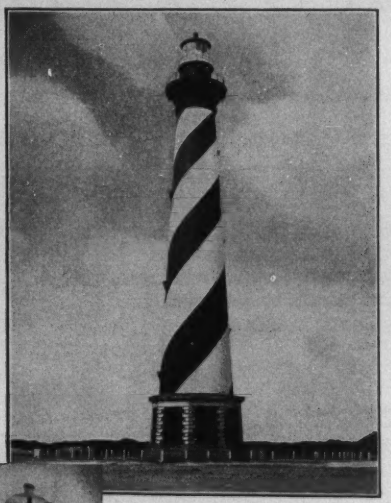
OF NEW ENGLAND

80 Federal Street Phone LIB erty 5993-4 Boston, Mass.

New England Representatives for

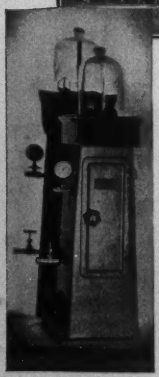
DE LAVAL STEAM TURBINE CO., TRENTON, N. J.

Dependable Chlorination



is the simplest Chlorination

"All progress is from the complex to the simple"



NOWHERE is progress from the complex to the simple more truly exemplified than in W&T Vacuum control chlorinators. • Complete elimination of diaphragms . . . . . springs . . . . . delicate control parts . . . . . plays an important part in establishing unusual performance records for this type machine. Every detail of its simple design reflects in trouble-free service—with average annual maintenance costs never more than 1% of the first cost. • Hydrostatic vacuum control—exclusive W&T feature—is the answer to dependable chlorination achieved in a simple manner. Today—install a W&T chlorinator and know how simple dependable chlorination can be. Ask for Technical Publication 38.

"The only safe water is a Sterilized Water"

WALLACE & TIERNAN CO.

INCORPORATED

Manufacturers of Chlorine and Ammonia Control Apparatus

NEWARK, NEW JERSEY Branches in Principal Cities

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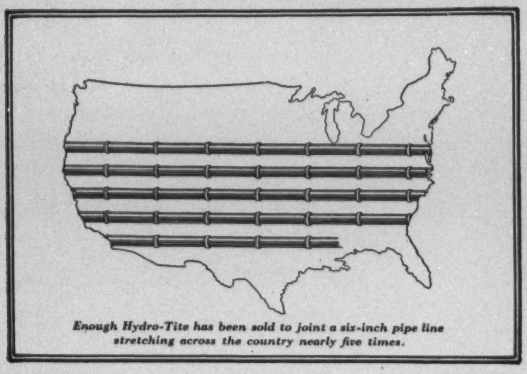
HYDRO-TITE

— *its record . . .*



Enough Hydro-Tite has been sold to joint a six-inch pipe line stretching across the country nearly five times.

HYDRO-TITE is always the same, comes in moisture proof, non-dusting bags, is shipped the day order is received. Every bag is subject to a guarantee which makes it impossible for you to lose by trying this modern pipe jointing material.

. . . over 21 years without a failure

Millions of joints in cast iron bell and spigot water pipe have been made with HYDRO-TITE.

In over 21 years not a single failure has been reported to us.

No wonder that year by year more waterworks men specify and use HYDRO-TITE and HYDRO-TITE equipment. They profit because HYDRO-TITE joints never blow out, leak 75% to 95% less than engineers specify for lead joints, withstand deflection and vibration, save 75% as compared with lead, require no caulking.

Write for HYDRO-TITE *data book*

Hydraulic Development Corporation

Main Sales Office:
50 Church Street, New York, N. Y.

General Offices and Works:
80 Boylston Street, Boston, Mass.

HYDRO-TITE

Reg. U. S. Pat. Off.

TODAY'S SELF-CAULKING WATER-PIPE JOINTING COMPOUND

Main's Hotcoating for the inside of standpipes and water tanks, will stop all pitting and corroding, and is guaranteed for seven years.

Also

Main's Coverall Salt Air Paint, for the outside of standpipes and water tanks, guaranteed for four years.

M. B. MAIN **Box 189, Somers Point, N. J.**

The "COREY" Hydrant

Why you should use GENUINE COREY HYDRANTS

Water to Nozzles quicker than other Hydrants.

Standpipe can be removed and replaced without shutting off water in main.

Ease of operation insured by knuckle joint principle.

Only 13 turns to completely open or completely close, but full flow with only 4 turns.

Nozzles screwed in — not leaded.

Can be lengthened without shutting off water.

Will not flood if broken.

Positive Drip — cannot freeze.

Standpipe can be revolved quarter turns — Nozzles always in right direction.

Write for copy of our new Catalog "G."

CHARLES L. BROWN,

New England Sales Manager, Lock Box 2, Northboro, Mass.

RENSSELAER VALVE COMPANY

TROY, N. Y.

DONALDSON IRON CO.

MANUFACTURERS
...OF...

CAST IRON PIPE

...AND...

Special Castings for Water and Gas.
Also Flange Pipe and Fittings.

Boston Office:
CHARLES F. GLAVIN
24 Milk Street

EMAUS,
LEHIGH COUNTY, PA.

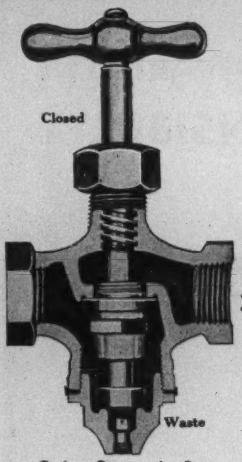
HIGHEST AWARD, GOLD MEDAL,
ST. LOUIS EXPOSITION, 1904

Over 100 Water Departments
use
LEAD-LINED IRON and TIN-LINED PIPES
for their service connections

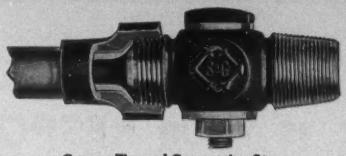
MANUFACTURED BY

Lead Lined Iron Pipe Company

Wakefield ═══════ Mass.



Gorham Compression Stop and Waste Cock



Copper Flanged Corporation Stop

S. & G. Water Works Brass Goods

S & D Heavy Pattern Slip Type Service Boxes

Byers' Wrought Iron Pipe

Annaconda Brass Pipe and Copper Service Tubing

Service, Roadway and Valve Boxes

Cast Iron Pipe and Fittings

SUMNER & DUNBAR

12-18 Pittsburgh St., Boston, Mass.

Telephone, LIBerty 1350

New England Water Works Association

Specifications and Meter Rate Sheets

Standard Specifications for Cast-iron Pipe and Special Castings, per copy, $0.25

Meter Rate Sheets:	Single sheet	0.05
	100 sheets, in orange	2.50
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PIERCE-PERRY CO.

Wholesalers of

Water Works Brass Goods.
Byers Wrought Iron Pipe.
Youngstown Steel Pipe.
Valve and Service Boxes.

236 Congress St., Boston, Mass.
Telephone, Hancock 7817-7818.

CEMENT LINED SERVICE PIPE

With Specially Adapted Lead-lined Fittings

Also Curb Cocks which eliminate Iron to Brass Corrosion both inside and out.

CEMENT LINED PIPE CO.
LYNN, MASS.

A PART-TIME FIRE DEPARTMENT IS YOUR RESPONSIBILITY

What possible good are trained firemen and expensive equipment without water? When they speed to dangerous fires and find broken, rusted or frozen hydrants, they are helpless.

That's *your* responsibility. Not only because of your position, but because *your* property needs the protection of ready water.

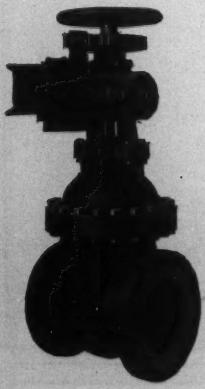
The one sure remedy is MATHEWS HYDRANTS

Mathews Modernized Hydrants need never be out of service, because when broken they can be instantly replaced—without costly digging or repaving. They don't rust or freeze because water never reaches the operating thread and they drain automatically.

Are your hydrants always ready? Write for the complete Mathews Modernized Hydrant story.

CAST IRON PIPE—SAND SPUN (Centrifugally Cast) AND PIT CAST
GATE VALVES Reg. U. S. Pat. Off. VALVE BOXES

R·D·WOOD & CO. ESTABLISHED IN 1803 · 400 CHESTNUT STREET PHILADELPHIA



Ready —

and instantly responsive

WATER-WORKS engineers and fire chiefs are naturally careful to select only apparatus that has definitely proven its thorough dependability as well as efficiency of operation.

The designers of pumping stations and fire protection systems all over the country choose Kennedy Valves and Fire Hydrants because the performance of Kennedy products has proven them to be always ready — and instantly responsive.

It will pay you to investigate Kennedy design and performance. Kennedy Water Gates and Fire Hydrants are built to conform with American Water Works Specifications and their many special features are based on over half a century of experience in this field.

THE KENNEDY VALVE MFG. CO.

Elmira, N. Y.

Branches in principal cities

KENNEDY

VALVES-PIPE FITTINGS-FIRE HYDRANTS

THE STANDARD FOR 50 YEARS

Automatic Pressure Control Valves
Feed Water Filters
Portable Fire Hydrants
Hydraulic Engines
Hydraulic Engines—Booster Pumps

ROSS VALVE MFG. CO., INC. TROY, N. Y.

Health and Protection First

Water delivered through dirty pipes may be a MENACE.

Incrusted water pipes mean inefficiency and loss of Fire Protection.

We Guarantee the Results of Our Method of Cleaning.

WRITE US.

National Water Main Cleaning Co.

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HAYES PUMP AND MACHINERY CO.

94 PEARL ST., BOSTON, MASS.

Pumping Plant Contractors

CENTRIFUGAL, POWER, STEAM PUMPS

STEAM TURBINES
WATER WHEELS

ELECTRIC MOTORS
OIL ENGINES

GOLDEN-ANDERSON

Patent Automatic Cushioned Controlling Altitude Valves

We have enlightened many a water user in municipalities, in industrial plants and on railroads, as to the adaptability of these Golden-Anderson Valves, and as to their function of SAVING, and of eliminating troubles.

For automatically maintaining Uniform Stage of Water in Tank, Reservoir or Standpipes. Doing away with the annoyance of Freezing and Float Fixtures inside or outside of Tanks.

"Three Ways of Closing These Valves":
1st —Automatically, by water.
2nd—By Electricity, if desired.
3rd—By Hand

May also be arranged to automatically close when a break occurs in the mains. When necessary they may be so connected as to "work both ways" on a single line of pipe. No valves or fixtures inside or outside.

Sizes to 24 in.

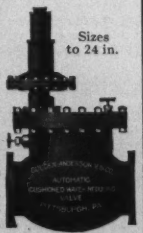
Remember!

"HOSTS OF REFERENCES"
Valves cushioned at all times by air and water
No water hammer or bursting mains

"Made with stop starter attachment for centrifugal pumps"

GOLDEN-ANDERSON
Pat. Automatic Cushioned Water Pressure Regulating Valves

1. Maintain a constant reduced pressure regardless of fluctuations on high pressure side.
2. Perfectly Cushioned by water and air. No metal-to-metal seats.
3. The best valve made for maintaining a constant low pressure where consumption is continuous.
4. Operates quickly or slowly as required — No attention necessary.
5. Positively no hammering or sticking.



Sizes to 24 in.

GOLDEN-ANDERSON
Patent Automatic Cushioned Controlling Float Valves

They carry a constant water level in feed water heaters by perfectly controlling the flow of makeup water.

Operated by protected enclosed copper float.

Cushioned by both air and water.

Operate without hammering, sticking or chattering. No metal-to-metal seats. Made angle or straightway.

Sizes 1 in. to 24 in.

GOLDEN-ANDERSON
Pat. Automatic Cushioned Water Float Valves

1. Automatically Maintain Uniform Water Levels in Tanks, Standpipes, etc.
2. Instantly Adjusted to Operate Quickly or Slowly.
3. Floats Swivel to any Angle — Most Satisfactory Float Valves Known.
4. No Metal-to-Metal Seats — No Water Hammer or Shock.
5. Cushioned by Water and Air.

Angle or Globe

Sizes to 24 in.

GOLDEN-ANDERSON
Patent Automatic Double Cushioned Check Valve

Sizes to 24 in. Angle or Globe

Automatically prevents reverse flow of pressure. Perfectly cushioned to prevent shock or hammer. Especially adapted for water works to prevent disastrous reverse flow of pressure due to pumps stopping. Arranged so that quick or slow operating may be obtained.

Golden-Anderson Valve Specialty Co., 1325 Fulton Bldg., Pittsburgh, Pa.

National-Boston Lead Co.

800 Albany St., Boston

Agents for

The Celebrated "ULCO"

LEAD WOOL

(Every Atom Pure Lead)

For calking pipe joints under the most difficult conditions.

For overhead joints, or in wet places where the use of molten lead is not only impracticable but dangerous — **LEAD WOOL** may be used to advantage.

It makes an absolutely tight joint which will withstand the highest pressure, yet be sufficiently elastic to allow considerable sagging or settling of the pipe without danger of a leak.

As compared with the poured joint, in this respect, the superiority of **LEAD WOOL** is apparent.

Manufacturers of

Lead Pipe, Tin Lined Lead Pipe, Pure Block-Tin Pipe, Solder, White Lead and Red Lead.

HIGHEST QUALITY SOFT BRANDS

PIG LEAD

Type of Eddy Hydrant Popularly Used

More Than Sixty Years of Experience Goes Into All

EDDY

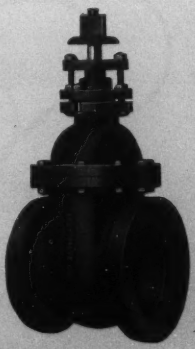
Hydrants and Valves

BUILT TO MEET EVERY EXACTING REQUIREMENT OF WATER-WORKS SERVICE

Practical water-works men instantly recognize the superior features of Eddy products. For instance, with the hydrant.

A damaged valve can be replaced in a few minutes — Water hammer is avoided by the valve closing against the pressure and the use of the cut-off under the valve, which gradually closes it —
Stems cannot be bent in closing the hydrant.
Nothing can lodge on the valve seat to prevent closing of the valve —
The Drip Rod can be removed without interfering with the hydrant in any manner —
The position of the stem of the hydrant indicates accurately the position of the valve —
Whatever can pass the valve opening will pass the standpipe —
No frost case necessary —
All of these points are explained thoroughly in our catalogue, which will pay you to study.

The Eddy Valve, Too



Has its distinctive and individual features. The double disk gates are free to adjust themselves in different positions every time the valve is closed, thereby keeping smooth and tight faces. And two bronze hooks on the ball loosely engage with the gates to prevent them from spreading at the top. The center bearing gates are forced to their seats with equal pressure at all points. There is a good deal more worth knowing about Eddy Valves. Further details will be sent for the asking.

Other Eddy Products

The Eddy line of water-works products also includes horizontal and vertical check valves, foot valves, hydraulically operated valves, indicator posts, etc.
All goods made by the Eddy Valve Company are manufactured exclusively at Waterford, New York.

WRITE FOR CATALOGUE

EDDY VALVE COMPANY

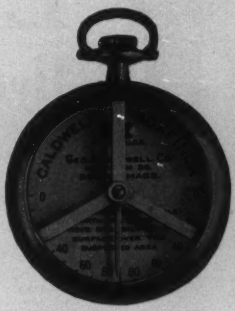
WATERFORD, N. Y., U. S. A.

DON'T DIG

"PIPEFINDR"

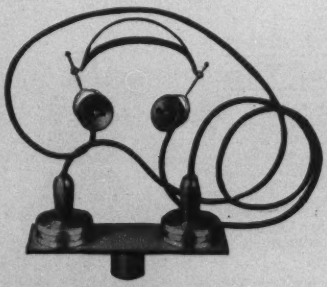
Actually TELLS you
Where IT is and
How DEEP it is

"BOXFINDR"



DURABLE
DEPENDABLE

"LEAKFINDR"



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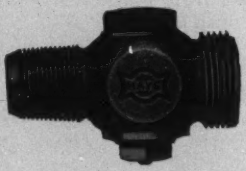
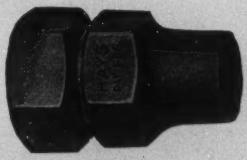
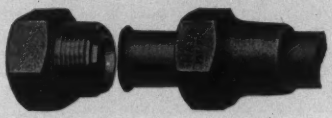


Regular Corporation Stop



Adapter

In making an installation with Hays Copper Service Fittings the regular Corporation Stops can be used in conjunction with the adapter. It is not necessary to procure new mandrels, as the Corporation Stops are inserted with the regular mandrels, in the usual manner, after which the adapter is attached.



Open View of Adapter

These adapters are made with Female Thread for Increased I. P., Water Works Standard or Lead Flange.

To use standard Corporation Stops with Increased I. P. or Water Works Standard Thread, and where a direct connection of the Corporation Stop and Copper Pipe is desired, the above stop has been designed. (See cut above for sectional view of joint.) These stops permit a Hays 90° seal with the use of regular male mandrels.

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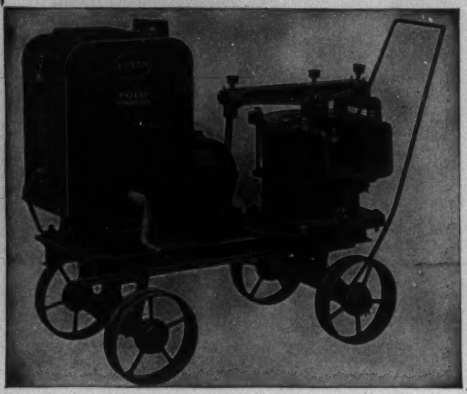

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BUMP!

JAR!

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